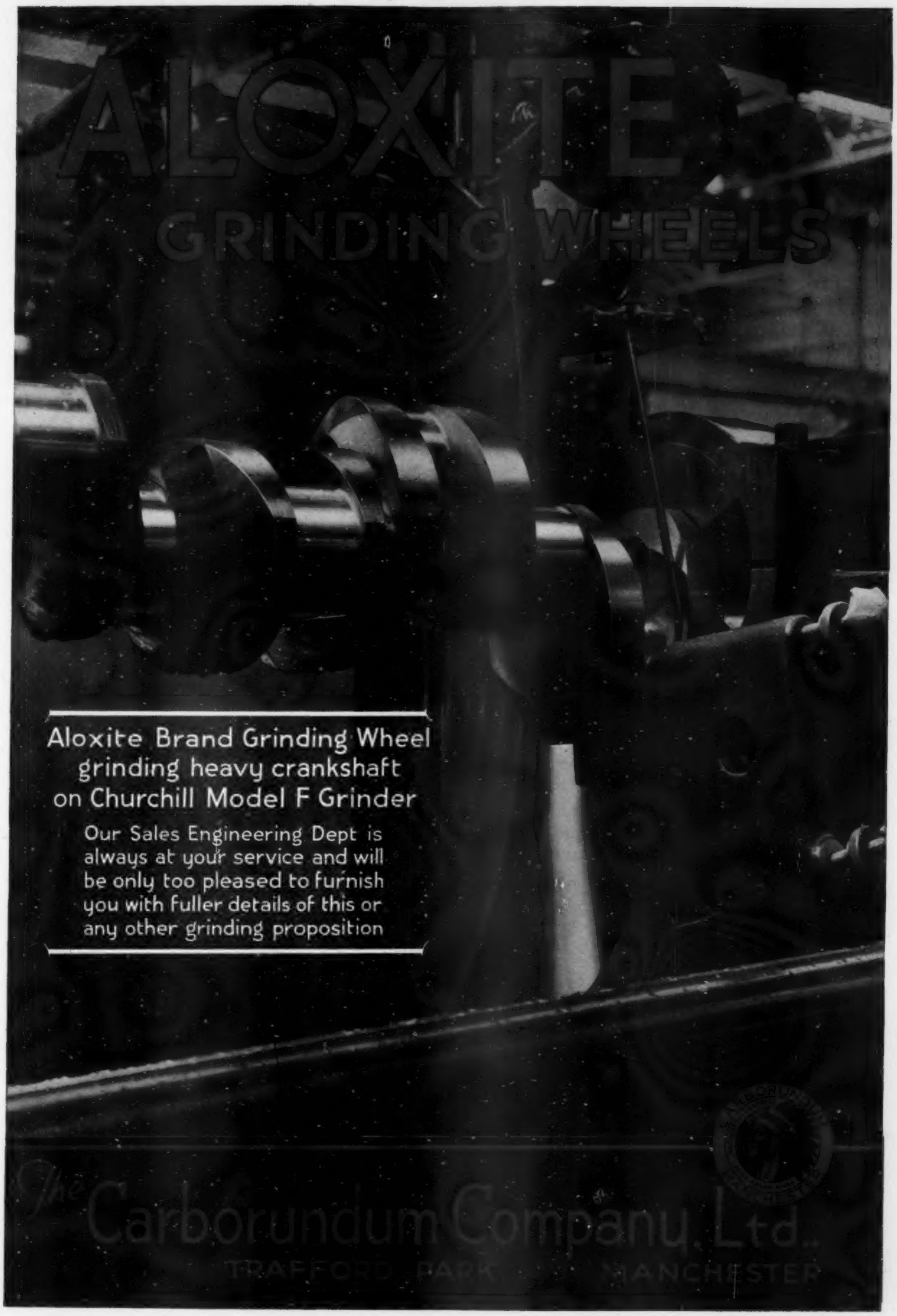
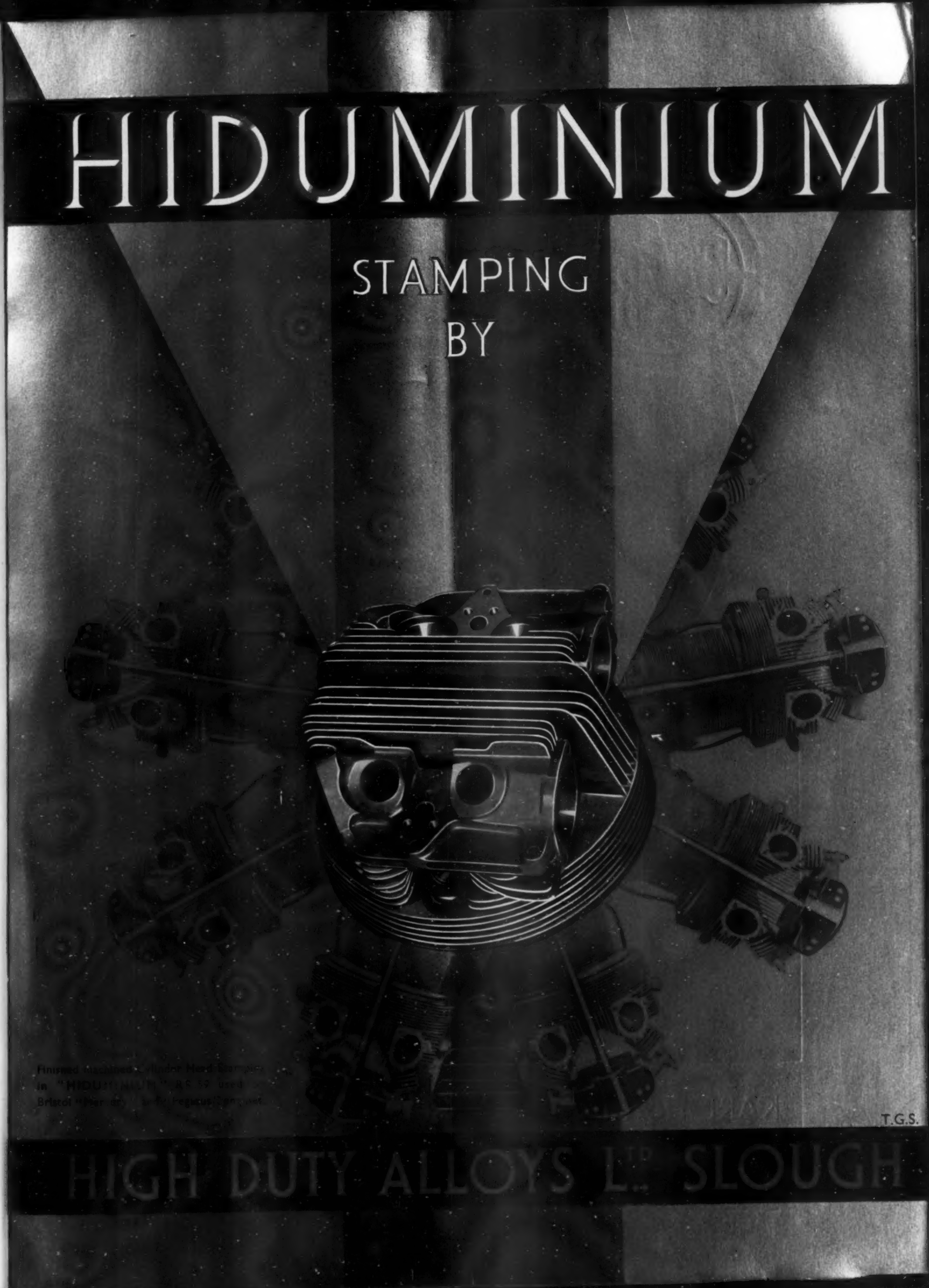
Vol. 16.—No. 94. AUGUST, 1937. Price 2/-. [Subscription 24/- per annum post free]

METALLURGIA

THE BRITISH JOURNAL OF METALS


ALOXITE
GRINDING WHEELS
Aloxite Brand Grinding Wheel grinding heavy crankshaft on Churchill Model F Grinder
Our Sales Engineering Dept is always at your service and will be only too pleased to furnish you with fuller details of this or any other grinding proposition
The Carborundum Company, Ltd.
TRAFFORD PARK MANCHESTER



HIDUMINIUM
STAMPING
BY
Finished Machined Cylinder Head Stampings
in "HIDUMINIUM" R.R. 59 used
Bristol "Mercury" and Pegasus Engines.
T.G.S.
HIGH DUTY ALLOYS L.TD SLOUGH

Visit our pavilion at the Great National Exhibition which is being held in Düsseldorf from May to October 1937

'Broduit' COPPER CONDUIT Installations

TRADE MARK

THE DISTRICT BANK, MANCHESTER :

"Broduit" Copper Conduit is used for the surface wiring installation in this magnificent new building.
Architect: Mr. Francis Jones, F.R.I.B.A.
Electrical Contractors: Drake & Gorham Ltd., Manchester.

THE "Broduit" Copper Conduit system has definite advantages over steel. There is no risk of corrosion; erection is simple, and the complete installation is neat and pleasing in appearance. Please write for a copy of the booklet "The 'Broduit' Copper Conduit System for Electric Wiring" published by I.C.I. Metals Ltd.

IMPERIAL CHEMICAL INDUSTRIES LIMITED

Dept M12 IMPERIAL CHEMICAL HOUSE MILLBANK, LONDON, S.W.1.

SALES OFFICES AT: BELFAST, BIRMINGHAM, BRADFORD, BRISTOL, DUBLIN, GLASGOW, HULL, LIVERPOOL, LONDON, MANCHESTER, NEWCASTLE-ON-TYNE, SHREWSBURY, SWANSEA.

'Broduit' is a registered trade mark, the property of the Broughton Copper Company Ltd., a subsidiary Company of I.C.I. Metals Ltd.

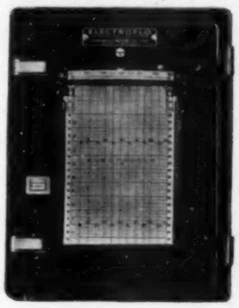
RELIABLE

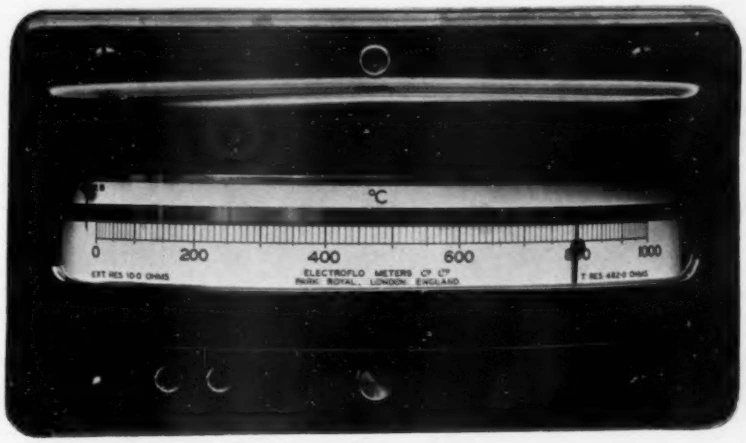
The best that can be said of a pyrometer is that it is *reliable*. "Attractive features" are no compensation for expensive "let downs," spoiled work and damaged furnaces.

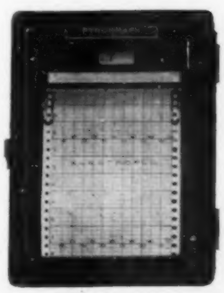
Reliability is fundamental, and can be ensured only by basically-sound design and first-quality materials and workmanship. The trouble-free service and maintained accuracy of Electroflo pyrometers have earned them the unqualified approval of every prominent furnace builder and innumerable pyrometer users.

Right. 10" Scale Indicating Control Pyrometer, a superior model of the *original* mechanically-operated mercury-switch control pyrometer

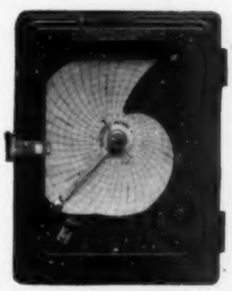
Below. A.C. Synchronous motor-driven Single or Multi-point Recording Pyrometer for up to six records, with 6" wide, 1,600 hour roll chart.



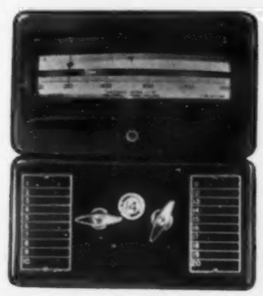




"Pyrograph" Temperature Recorder—single or two record—with spring-wound clock driven, 6" wide 1,600-hour roll chart.



Programme Controller for use with Electroflo Control Pyrometers with specially cut cams to maintain any desired time/temperature cycle.



Single or Multipoint Indicating Pyrometer with totally-enclosed double-pole rotary switch and automatic station indicator.

★ Interested Metallurgists and Plant Engineers are invited to write for fully descriptive catalogues and interesting articles on Automatic Furnace Temperature & Atmosphere Control

ELECTROFLO PYROMETERS

INDICATING ★ RECORDING ★ CONTROLLING

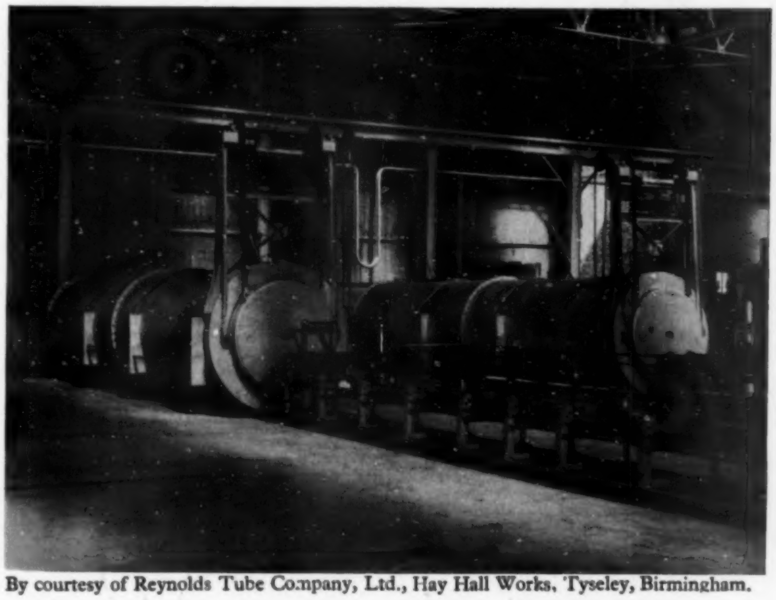
MAKERS OF THE ORIGINAL MECHANICALLY OPERATED MERCURY-SWITCH CONTROL PYROMETER

Advt. of:—ELECTROFLO METERS COMPANY LTD., ABBEY ROAD, PARK ROYAL, LONDON, N.W.10

EFCO

FORCED AIR FURNACES

FOR THE HEAT TREATMENT OF ALUMINIUM ALLOY TUBES AND SECTIONS



By courtesy of Reynolds Tube Company, Ltd., Hay Hall Works, Tyseley, Birmingham.

Two EFCO Horizontal Forced Air Circulation Furnaces for the heat treatment of tubes and sections up to 25 ft. long.

EFCO

ELECTRIC FURNACE COMPANY LIMITED

ELECTRIC RESISTANCE FURNACE CO. LTD.

17 VICTORIA STREET, LONDON, S.W.1

TELEPHONE ABBEY 4171 (7 LINES) TELEGRAMS ELECTRIFUR PHONE LONDON

METALLURGIA

The British Journal of Metals

(Incorporating The Metallurgical Engineer.)

Contributions suitable for the editorial pages are invited. Photographs and drawings suitable for reproduction are welcome. Contributions are paid for at the usual rates.

PRINCIPAL CONTENTS IN THIS ISSUE:

Subscription Rates throughout the World - - 24/- per annum, Post free.

Published Monthly by the Proprietors, THE KENNEDY PRESS LIMITED, at 21, Albion Street, Gaythorn, Manchester.

Telegrams: "*Kenpred,*" *Manchester.* *Telephone: Central* 0098.

METALLURGIA

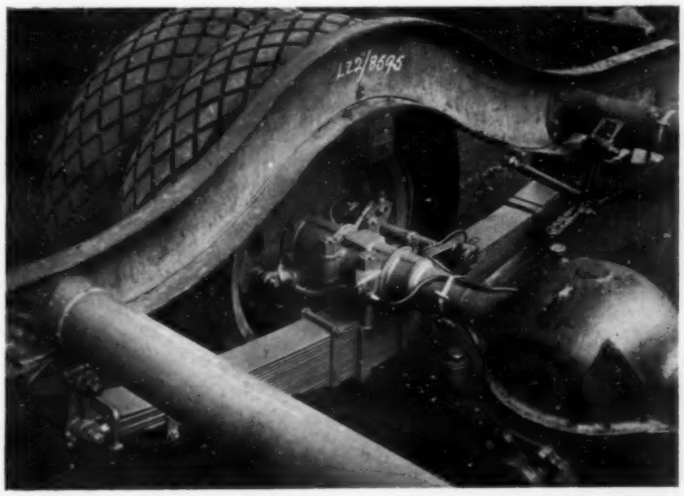
THE BRITISH JOURNAL OF METALS.
INCORPORATING "THE METALLURGICAL ENGINEER".

August, 1937. Vol. XVIII, No. 94.

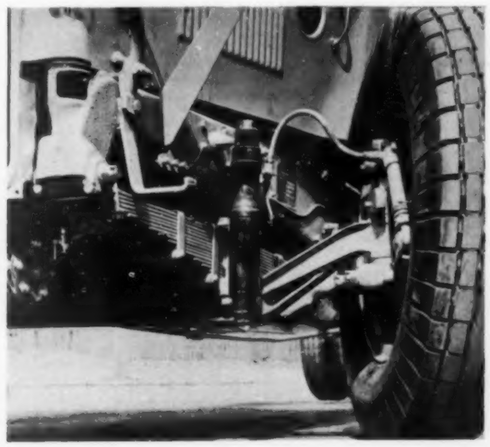
Spring Production for Road Transport Vehicles

Developments at the Works of Samuel Fox and Co., Ltd.

A new road-vehicle spring-making plant which has recently been installed at the works of Samuel Fox and Co., an associated company of United Steel Companies, Ltd., is described. It is the most modern of its kind in this country, and is designed to maintain the high quality of the well-known Fox springs and to raise production to meet increasing demands.



Rear spring on 6-wheeler bogie.



Courtesy of Leyland Motors, Ltd.

Front spring with with patent anchor clips.

With improved roads and rapid engineering progress road transport has made remarkable strides in recent years. This is particularly true of what may be regarded as the heavy road vehicles, such as omnibuses, coaches, and lorries. In keeping with developments, there has been a growing degree of steadiness in the vehicles in service, a factor which enhances the comfort of road travelling, ensures the transport of goods with the minimum of disturbance, increases the serviceable life of the vehicle, and contributes to greater safety.

While many factors contribute in providing a high degree of comfort and maximum service, the influence of well-designed and properly constructed springs is now recognised to be not the least important. It will, therefore, be of interest to give some details of a new plant specially designed for the production of springs suitable for vehicles of the types mentioned. The works at which this installation has been effected are those of Samuel Fox and Co., Ltd., at Stocksbridge, a firm which has achieved remarkable success in the manufacture of springs for commercial vehicles, so much so that to-day over 60% of British buses, coaches, and lorries run on Fox's springs.

The position this company has achieved is the result of quality of product, coupled with efficient organisation, but in keeping with the general scheme or reorganisation, which has been proceeding at these works for some years, more efficient production was aimed at. With this in view, intensive thought and application has resulted in the installation of a new spring-making plant which is almost entirely automatic and which is in every way superior to previous methods of manufacture. It is, in fact, claimed to be the most modern spring-making plant, not only in Great Britain, but throughout the world.

High-quality Springs

The value of high-quality springs for road vehicles cannot be over-estimated : as is well known, there are always running shocks beyond the value of the weight carried, and inferior road surfaces intensify these shocks. The faster the vehicle is permitted to travel the more powerful do these shocks become, and consequently the more destructive to the roads and to the vehicle itself, without mentioning the discomfort to passengers or damage to goods being transported. To dampen the transmission of these shocks is the function of the springs, and the faster the vehicle is designed to travel the greater is the need for perfection, not only in the arrangement of the springs, but in the quality of material used and in the technique of their manufacture.

The type of spring used for road vehicles is the laminated spring ; its design depends upon the static and dynamic load, the disposition of the centre of gravity, the ratio of spring centres to the road, coefficient of friction between the wheels and the road, braking effects, etc., but the great principle underlying the spring is the elasticity of the steel of which it is built. Normally, when a spring plate is

Feeding plates from preheating furnace to forging machine.

deflected a stress is imposed on its surfaces and through its sections, implying that a corresponding force in the plate has been required to resist and control the applied load. This internal force may be required to resist tension, compression, shearing, or torsion, but whatever the nature of the external force, the resistance of the plate should be its elastic equivalent, otherwise its elastic strength will be exceeded. When designing laminated springs all these factors are jointly considered in relation to the running shocks which are always in excess of the static loading. Whatever form the spring may take, its effectiveness is dependent upon its elasticity, this being the amount a spring will deflect under a given load without having its form permanently changed. The amount a spring will bend under a given load is dependent on the number of plates, their thickness, length, and breadth, on the material of which they are made, and how that material is hardened and tempered. In specifying or designing springs for a given vehicle, the periodicity of front and rear springs has to be calculated, to result in satisfactory suspension characteristics.

In the arrangement of the plates it is considered to be an advantage to arrange each succeeding plate so that the ends of each conform to the straight line principle. This method equalises the elasticity of the spring, but a sufficient number of plates are necessary to give adequate strength about the eye attachments as well as the centre. Modifications of this principle are made, depending upon the method of suspension. At one time it was customary to make one long plate in the spring thicker than the remainder, but modern practice favours the use of plates of similar thickness throughout. It will be appreciated that the greatest permissible deflection, up to the breaking-point of the spring, decreases inversely with the cube of the thickness of the plate which is used, and its supporting power for the same maximum stress increases with the square of the thickness. Thus for a given deflection a thick plate must bear a greater comparative load.

Automatic quenching to harden the cambered plates.

In the manufacture of laminated springs for road vehicles, no firm has contributed more to their improvement than the firm of Samuel Fox and Co., as the increasing demands made on its production capacity testify. Improvement has resulted not only from superior design, developed after long experience of service conditions, but also by the use of steels of high and uniform quality, improved treatment of the steel as a result of a fuller knowledge of its properties, and the use of equipment which is under accurate control. Messrs. Samuel Fox and Co. have made a speciality of laminated spring manufacture for many years, and with full knowledge of the requirements of the product, have been able to give the closest possible investigation to each operation in manufacture, from the making of the steel to the final testing of the finished spring.

Spring Steels

Several steels are used for laminated springs which include straight carbon steel, silico manganese steel, and chrome-vanadium steel. The quality of carbon steel employed is an open-hearth steel designed for water hardening, and has the following composition :—

Carbon.	Silicon.	Manganese.	Sulphur.	Phosphorus.
0·5–0·55	0·10–0·55	0·65–0·75	0·04	0·04

The tensile strength of this steel as rolled would be to be 45–50 tons per sq. in., while after tempering it should have a tensile strength of 85–95 tons per sq. in. and an elastic limit of 55–60 tons per sq. in.

A typical composition of chromium-vanadium steel comprises 0·45 to 0·50% carbon, 1·0 to 1·1% chromium, and 0·15 to 0·20% vanadium. These steels may be treated to give a tensile strength of 100 tons per sq. in. and to possess a high elastic limit.

In this country the silico-manganese steels are more commonly used for these springs, especially for road vehicles, and compositions vary between comparatively narrow limits and contain 0·5 to 0·55% carbon, 1·80 to 2·0% silicon, and 0·8 to 0·9% manganese. Silicon raises the critical point, and the steel must therefore be heated to a higher temperature for hardening than for corresponding plain carbon steels. The springs are usually oil-quenched from 875° to 900° C., and when tempered at 500° to 550° C. give Brinell hardness numbers of about 415 to 444. In this condition uniform hardened and tempered structures obtain, and the steels are characterised by their toughness and resistance to fatigue. In order to obtain the best results with these steels the heat-treatment must be carefully carried out, and it is very desirable to control the temperature limits of both hardening and tempering as closely as possible.

Laminated springs from the usual spring steels are manufactured by Messrs. Samuel Fox and Co., but because of the demands of the trade silico-manganese steel predominates. The materials used at these works are received in the bar stock shed, located at the end of the spring shop, in various sizes and qualities to meet varying requirements and specifications.

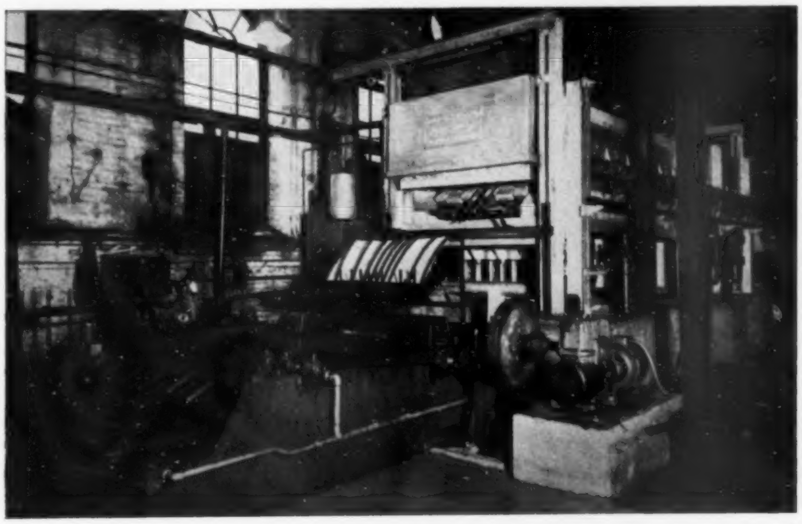
Spring Manufacture

The reorganisation of the spring shop has been carried out during a period when heavy demands were made on production, and it speaks highly for the executive ability that clients were kept supplied with consignments of finished springs. The flow from the stock shed to the testing of the finished spring is practically on the straight-line principle, and the whole of the line of flow is fed by an efficient " Telpher " system which covers every machine and furnace. Throughout the line of manufacture regular test checks are made for accuracy in production and quality of material.

The long bars are received from the stock shed and sheared into the respective plate lengths. Those lengths required for back plates and the plates which require rolled eyes are heated at the ends in small furnaces and passed to a single stroke eye-forming machine, when a finished rolled eye is produced in one stroke and the plate having a predetermined length. The eye-forming machine is of modern design, having single-stroke operation.

The plates pass on to a preheating furnace. This is the first of three new furnaces recently installed, all of which give continuous operation. These have been designed and constructed by the Incandescent Heat Co., Ltd. Their design has been determined in close collaboration with Mr. Stirling, the departmental manager, and they operate automatically. In addition to the preheating furnace there are also hardening and tempering furnaces.

These furnaces are designed, in keeping with modern practice, to retain a temperature within a definite predetermined range. They provide for convenient loading, with due regard to the method of exposing the plates to the heat, so that each plate will be subjected to the same temperature for the same time and in the same manner as every other plate; special high-pressure gas burners control both gas and air supply to the furnaces. The preheating furnace is of the walking beam type, which automatically discharges the plates, which have been heated to a temperature of 700° C.

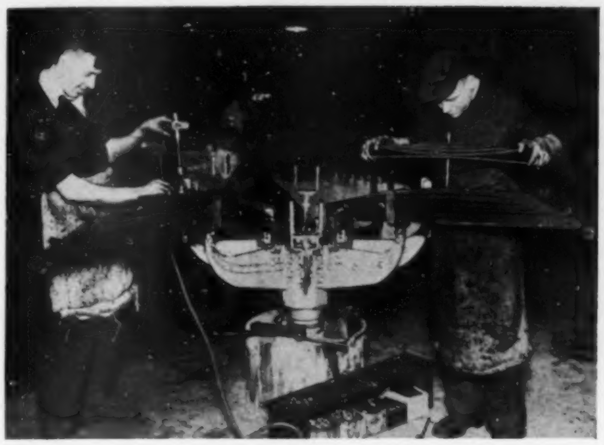


The hardening furnace by The Incandescent Heat Co., Ltd. with the cambering machine as an integral part of the equipment.

The hot plates are transferred to a large forging press, where the centre dimple and the shaped end of the plate are formed in a single stroke of the machine and automatically discharged to an elevator by which they are transmitted to a mechanically operated hardening furnace, which is maintained at a suitable temperature, depending upon the type of steel being used. At the time the writer inspected these furnaces in operation, silico-manganese steel springs were being manufactured, and the hardening furnace was operating at a temperature of 900° C.

The plates are discharged from the hardening furnace on to a landing table, from which they are lifted to a cambering machine, which bends each plate to shape and automatically quenches it in oil, subsequently discharging it from a walking beam conveyor. This machine is designed for handling all curvatures of plates, as well as width and thickness, within the commercial vehicle range. The hardened plates are afterwards packed in special boxes in single layers and passed on to the walking beams of the tempering furnace.

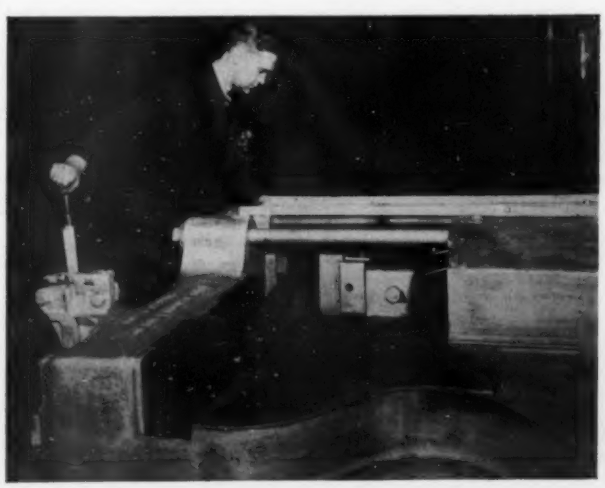
The tempering furnace is also mechanically operated, and works at a temperature of approximately 500° C., consistent with the treatment required. The boxes of plates are landed on to a roller table at the outlet end of the furnace, where the plates are water-quenched and the boxes stacked.



Assembling the plates to form complete springs.

These furnaces are of the high-pressure gas type, divided into three zones, which are separately electrically controlled to a predetermined range of temperature. An indicating lamp is mounted on a panel within sight of the operator. Coke-oven gas of 500 B.th.u.s per cubic foot is used, and extreme care is taken in the amount of air admitted to the burners to obtain complete combustion at the nozzles of the burners. The hardened and tempered plates are subsequently ground at the ends, and auxiliary fittings, such as side shackles, are assembled, the plates being mounted on completion on to a rotating table assembly, the eyes being reamered in a two-spindle machine, and the complete springs assembled and passed to skid conveyors. The springs are then scrag tested to a predetermined stress and to a given camber height. Bushes are afterwards inserted as required, the edges of the eyes are ground to width, and the springs are weight-tested,

A finished spring undergoing the scrag test.



completing the sequence of operations. Beyond this point an independent inspection system takes over the springs and each is individually examined and passed forward for dispatch.

This plant, operating under full production, is capable of giving an output of 30 cwt. per hour, and the results so far obtained are remarkable, more particularly in regard to quality and uniformity of product. Those familiar with the ordinary methods employed in spring production will appreciate the great advance this new plant represents.

It is noteworthy that the spring department is only one of the departments which is included in the reorganisation scheme of Messrs. Samuel Fox and Co.; considerable developments are in progress in the wire shop, not only as a result of new installations, but the shop itself is being increased to about twice its former size. The same applies to the cold-rolling shop, which is undergoing considerable alteration. In the high-frequency steel-making shop, which was built and equipped about four years ago, the success achieved has been such that a new large high-frequency melting plant is being added to the equipment to deal with the increased demand for "Diamet" steels. Among further developments in progress is the stainless sheet department, where considerable extensions are being carried out.

It will be realised that the United Steel Companies, Ltd., despite the heavy pressure of business, are continuing to maintain their various constituent works equipped for quality production on an economical scale.

Some Tin Researches

SEVERAL further publications have been issued with the object of disseminating scientific and technical knowledge relating to tin, its alloys, and chemical compounds, the processes involved in the production of these materials, and their applications. These are briefly discussed under their respective titles in the following notes :—

Tinning Steel Strip by Electrodeposition

Recent developments in the rolling of large ingots of steel into continuous strip suitable for tinplate manufacture have created the need for a satisfactory continuous tinning process. Difficulties with the hot-tinning method have stimulated work on electro-deposition which is so often adaptable to continuous conditions. In this paper, by D. J. Macnaughton, W. H. Tait, and S. Baier, various factors affecting the nature of the tin coatings produced by continuous electro-deposition on a strip 2 in. wide have been investigated.

The characteristics of both alkaline and acid baths are discussed ; satisfactory coatings were obtained with each, but the acid bath is preferred. With the acid bath it would appear to be possible to electro-tin at speeds comparable with those used in hot-tinning, while keeping the length of the bath within practical limits.

Coatings vary from rough matte to smooth matte, or even semi-bright, but all require polishing to make them bright. Quantitative data on polishing were obtained by means of a specially devised apparatus, allowing control of the pressure and speed of the polishing mop. By providing a transverse movement for the specimen the amount of polishing given to parallel strips could be controlled, and the drag of the specimens under the mop was also measured. With the various polishing materials investigated the loss due to polishing ranged from 7 to 20% of the weight of the coating ; for smooth matte it was about 10–13%, and porosity was doubled by it. Scratch-brushing caused less loss than polishing, but the porosity was much greater except in the case of brass-wire brushes which did not increase it much.

The electro-deposited coatings produced by the methods described in the above paper were examined by D. J. Macnaughtan and J. C. Prytherch, to see how they behaved when the strip was deformed. This is important, because tinplate is usually deformed during fabrication.

To provide a basis for comparison, tinplate made by hot-dipping was also put through the tests of stretching and close-bending. Commercial samples of hot-dipped tinplate with coatings of 0·00012 in. and 0·0003 in. were used, and the effect on porosity was examined. The protective value of the coatings in the unstretched condition was very different from that after stretching-smooth matte coatings being greatly superior to the rough matte. The authors discuss the factors responsible for the behaviour of the tin coatings under deformation and the possible effect of the steel base.

The Effect of Cold Work on the Hardness of Pewter

Three alloys of tin with antimony in the proportions of 3, 5, and 7% were investigated both without and with the addition of either copper or silver in substitution of part of the tin; the results are discussed in this paper by R. E. Leyman. The copper additions, approximating to ½, 1, and 3%, were made only to the 5% antimony alloy, while the silver was introduced in the same proportions in the 7% antimony alloy. Ingots of these compositions were reduced in thickness by repeated rolling, the reduction per pass being about 1%. Tests of Brinell hardness and examination of micrographic structure were made on specimens with reductions of from 10 to 80%. All alloys were hardened by moderate cold-rolling down to 40 or 50%. Further rolling softened them, the softening becoming more pronounced with the higher proportions of copper and silver. Annealing caused further softening in most cases, but some of the copper and silver alloys which had been severely worked improved slightly in hardness. Various quenching and ageing treatments were tried, but were without permanent effect.

Estimation of Cadmium in Tin-rich Alloys

Volatilisation of cadmium from alloys rich in tin can be made so complete without appreciable loss of tin that it has been adopted as a method of analysis. In this publication, Professor D. Hanson and Dr. W. T. Pell-Walpole describe the procedure they have developed during their investigations on the constitution of alloys of cadmium and antimony with tin.

The alloy is weighed into porcelain combustion boats, which are then maintained at 700–730° C. for 30 mins. in a silica tube connected to a vacuum pump to assist the volatilisation of the cadmium. Several estimates may be made simultaneously. The degree of accuracy was checked and found to be perfectly satisfactory.

Electrodeposition of Tin from Acid Sulphate Solution

Although acid baths for electro-deposition of tin are attractive because of their high efficiency and the fact that they can be worked at room temperature, they suffer from the disadvantage that they are unstable solutions and the deposits tend to be patchy and in loosely adherent needles. To some extent addition agents enable these drawbacks to be overcome. Further research to improve these addition agents has been carried out, and in this paper A. W. Hothersall and W. N. Bradshaw show that additions of sulphonic acids, such as those of cresol, phenol or benzene are ineffective when the acids are pure. Crude qualities, however, contain certain by-products of sulphonation which enable smooth deposits to be obtained especially when gelatin is present, but the solutions deteriorate rapidly and have poor covering power. Hydroxy compounds of the aromatic hydrocarbons, such as β-naphthol and resorcinol, are most effective, and they can be used with gelatin or the more stable lysalbic acid which is prepared from egg albumen. A solution was found which had good covering and throwing power and was substantially unimpaired after long use.

METALLURGIA

THE BRITISH JOURNAL OF METALS.
INCORPORATING "THE METALLURGICAL ENGINEER"

Raw Material Problems in the Iron and Steel Industry

THE exceptionally heavy call for iron and steel, which has been experienced for some time, has raised many problems associated with production which are causing some anxiety among manufacturers. Before and since the depression the major problems of the industry were concerned with economical production for which considerable reorganisation and reconstruction was recognised as essential; few manufacturers, however, were prepared to embark on costly reorganisation schemes without some reasonable guarantee in the home market, and, as is well known, a protective tariff was instituted and a pledge given to reorganise the industry. Since that time much has been done by the industry to redeem the pledges which formed part of the agreement, and to-day consumers, as well as iron and steel manufacturers, are benefiting from the greatly increased production resources.

All readers familiar with the British iron and steel industry will appreciate the increasing cohesion of its internal organisation and the rapid progress of its technical reconstruction. Technically, the advances made in recent years are of a very high order. Plants have grown larger and more efficient, better co-operation is displayed between the various sections of the industry, and recognition of the principles of fuel economy is now firmly established.

Practically every manufacturer of iron and steel has carried out or is carrying out some major development scheme, primarily with the object of increasing production by the most economical operations available, with due regard for the conditions existing in any particular plant. Many examples of these advances have been described in this journal, but brief mention may be made of the developments of the United Steel Companies, Ltd., which are likely to be supplemented in the near future by the rebuilding of the Lincolnshire plant; the huge new plant of Stewarts and Lloyds, erected on virgin ground at Corby; the amalgamation of the heavy steel interest of Guest, Keen and Nettlefolds and Baldwins, which culminated in the construction of the Guest, Keen, Baldwins plant at Cardiff. Mention may also be made of the developments at Dorman Long's and Colville's, and to the modern strip mill technique being introduced by Richard Thomas at Ebbw Vale; such firms as the English Steel Corporation and Thos. Firth and John Brown, Ltd., have also made great advances, in fact it would be impossible to mention a firm which has not carried out some reconstruction scheme.

These developments have greatly increased the capacity of the various plants, and production figures bear witness to the value of the work done and the advances made. Before the slump it was generally recognised that the British iron and steel industry was, in many respects, behind that on the Continent; to-day, however, the progress is such that many British plants compare favourably with any in the world, and it is important to observe that, even though plants are working under heavy pressure, reconstruction is continuing.

The demand for iron and steel, which has been growing rapidly since the slump, has raised another problem which is intensified by reconstruction and increased production; this problem is concerned with raw materials. Actually, it has been a pressing problem for some time, due to the great expansion in demand for iron and steel, a demand which is not confined to this country. Consumers continue to complain of inadequate supplies, and producers, in many instances, are only able to meet requirements on a hand-to-mouth basis which may avoid temporary difficulties, but, usually, involves the consumer in additional costs. With unlimited supplies of raw materials, manufacturers would still be under pressure to meet present demands, but they would be able to operate nearer to full capacity, and less anxiety would be felt for future supplies of iron and steel.

The iron and steel industry depends largely upon ample supplies of coal, ore, and scrap for economical production, and although Great Britain has large coal deposits, she is dependent to a considerable extent on foreign supplies of the other raw materials. There are, of course, considerable supplies of iron ore in this country, but the iron content is relatively low, apart from the hæmatite ores, and foreign ores of larger iron content are imported to supplement the supply of native ores. Although formerly pig iron predominated in the manufacture of steel, scrap now plays a very important part. At one time the production of pig iron exceeded that of steel, but in recent years, as a result of the extended use of scrap, the position has been reversed and the amount of scrap used in the manufacture of steel now exceeds that of pig iron, much of which is imported.

Consumption of different raw materials—that is, foreign or native ores and scrap—per unit of output, varies considerably in different producing districts. On the North-East Coast, for instance, the low-grade Cleveland ores and Spanish ores are smelted in about equal quantities of iron content; low-grade native ores are mainly consumed in the Midland producing area embracing Derby, Lincolnshire, Leicester, Notts., and Northants; the low-phosphoric ores of Cumberland provide the North-West Coast producers, this is supplemented with ore from Spanish and North African mines in the approximate ratio of about two of native ore to one of imported; only about one-third of the ore used in South Wales and Monmouthshire is from home resources, the remainder is obtained from abroad; Scotland depends almost entirely on foreign ore supplies; Lancashire and Yorkshire obtain about one-quarter of their ore requirements from abroad, while remaining districts operate largely on home supplies. British steel is produced mainly by the open-hearth process, and while many districts use pig iron with a relative low percentage of added scrap, other districts use more scrap than pig iron.

It can be stated that roughly half the pig iron produced in this country is derived from foreign ores, and of the scrap used in steel-making about 20% is imported; it will be appreciated, therefore, that regular supplies of these raw materials are of vital importance to iron and steel plants. For some time now supplies have not been regular, a raw material stringency has, in fact, been experienced which may become more marked in the future unless some remedy can be found. Difficulties have been experienced in obtaining regular supplies of Spain and Spanish Morocco ores, and substantial changes in this trade have resulted in recent years; for instance, imports from Algeria and Tunis and those from Sweden have increased, while there has been a substantial reduction of the import of Spanish ores. Increased activity in other European producing

countries create difficulties in obtaining supplies of ores from other European resources, and supplies have been obtained from Empire resources, notably from Newfoundland, but the problem of higher freights has prevented development on these lines. It is probable, however, that this method will assist to an increasing extent as the import of European ores become more difficult. To some extent this problem is political and will only be solved by international co-operation, which at the moment does not seem a practical proposition.

Forthcoming Meetings

Institute of Metals

The twenty-ninth annual autumn meeting will be held in Sheffield on September 6–9. The Autumn Lecture will be given by Dr. D. R. Pye, C.B., M.A., F.R.S., on September 6, at 8 p.m., the subject being "Metallurgy and the Aero Engine." At the subsequent technical meetings held on September 7 and 8, the following papers will be presented for discussion :—"Copper-Rich Nickel-Aluminium-Copper Alloys" Part I—"The Effect of Heat-treatment on Hardness and Electrical Resistivity," by W. O. Alexander and D. Hanson ; "The Constitution of the Nickel-Aluminium System," by W. O. Alexander and N. B. Vaughan ; "The Methods of Testing Zinc Coatings," by L. Kenworthy ; "The Mechanical Properties of Some Metals and Alloys Broken at Ultra High Speeds," by D. W. Ginns ; "Precision Extensometer Measurements on Tin," by B. Chalmers ; "A Study of the Deformation of the Macrostructure of Two-phase Alloys by Cold Rolling," by H. A. Unckel ; "The Transformation in the Beta Brasses," by C. Sykes and H. Wilkinson ; "A Study of the Mechanical Properties of Tin-Rich Antimony-Cadmium-Tin Alloys," by D. Hanson and W. T. Pell-Walpole ; "The Determination of Alumina in the Presence of Metallic Aluminium," by G. B. Brook and A. G. Waddington.

If time permits, further papers to be discussed will include :—"Alloys of Magnesium" Part VI.—"The Constitution of the Magnesium-Rich Alloys of Magnesium and Cadmium," by J. L. Haughton ; "The Constitution of the Tin-Rich Antimony-Cadmium-Tin Alloys," by D. Hanson and W. T. Pell-Walpole ; and "The Constitution of the Copper-Gallium Alloys in the Region 18 to 32 Atomic Per Cent. Gallium," by W. Hume-Rothery and G. V. Raynor.

The programme for this meeting includes several interesting works visits and important functions, while a comprehensive programme is arranged for ladies.

Iron and Steel Institute

The autumn meeting will be held in Middlesbrough, on September 14–17, for which a programme of technical meetings, works visits, excursions, and entertainments has been arranged. The works visits, in particular, are very comprehensive, and will give members an opportunity of seeing the progress achieved in this area. The papers to be presented at this meeting include :—"An Investigation of a Blast Furnace Smelting Principally Lincolnshire Ores at the Frodingham Works of the Appleby-Frodingham Steel Co., Ltd.," by the Blast Furnace Reactions Research Committee of the Iron and Steel Industrial Research Council ; "Foamed Blast-furnace Slag," by T. W. Parker ; "Some Experiments in a Small-scale Cupola," by H. E. Blayden, W. Noble, and H. L. Riley ; "The Influence of Carbonising Conditions on Coke Properties," by H. E. Blayden, W. Noble, and H. L. Riley ; "The Mechanism of Nitride Hardening," by M. S. Fisher and Z. Shaw ; "Hot Melting Practice in Five Melting Shops on the North-East Coast," by W. Geary ; "The Thomas-Gilchrist Basic Process, 1879-1937," by Frank W. Harbord, C.B.E. ; "Variation in Thickness of the Tin Coating of Tinplate, and Its Effect on Porosity," by W. E. Hoare ; "Some Alloys for Use at High Temperatures," by C. H. M. Jenkins, E. H. Bucknall, C. R. Austin, and G. A. Mellor ; "Further Experiments on the Nitrogen-Hardening of High-Chromium and Austenitic Steels," by B. Jones ; "A New Method for Judging the Behaviour of Iron Ores During Reduction," by N. J. Klärding ; and "Some Notes on Recent Experiments in Connection with the Spraying of Steel by the Wire-fed Spraying Pistol," by R. R. Sillifant.

Joint Committee on Materials and Their Testing

The first technical discussion under the auspices of the Joint Committee will be held in the Large Hall of the College of Technology, Manchester, on Friday afternoon and evening, October 29, commencing at 2-30 p.m., and terminating at 7-30 p.m. approximately. The following papers on notched bar impact testing have been promised :

Paper No. 1.—"The Physical Meaning of Impact Tests," by Professor R. V. Southwell, M.A., F.R.S., University of Oxford.

Paper No. 2.—"Some Aspects of the Notched Bar Test" (in two sections—namely, a brief review of past experiments in this country and an experimental exemplification of several features of the test), by Mr. L. W. Schuster, M.A., British Engine Boiler and Electrical Insurance Co., Manchester.

Paper No. 3.—"The Development and Present Position of Continental Research on the Notched Bar Impact Test," by Dr. Ing. Max Moser, Messrs. Fried Krupp, Essen.

The Manchester Association of Engineers, who are organising the meeting, have undertaken to supply advance copies of the papers and to publish the complete proceedings. Applications for tickets of admission and for advance copies of the papers (for which a small charge will be made to cover cost of printing) accordingly should be made to the Secretary, Manchester Association of Engineers, St. John Street Chambers, Deansgate, Manchester, 3, who would also be pleased to receive notifications of intention to take part in the discussion either orally or by written communication.

Cavitation Erosion

Mention is made elsewhere in this issue of some work which has been carried out on cavitation erosion. This subject is a difficult one, and relatively little experimental investigation has been published, but it is of interest to note that Kerr* has carried out an investigation on the determination of the relative resistance to cavitation erosion by the vibratory method.

The investigation was made in connection with the selection of the most suitable materials for the construction of the large hydro-electric units for the Passamaquoddy project. Tests were made on 80 materials in a newly developed vibratory apparatus to obtain an indication of the behaviour of materials in sea water as compared with fresh water, and the relation between cavitation damage and temperature.

Of the non-ferrous materials, aluminium-bronze was found to stand at the top of the scale for both cavitation erosion and initial resistance to cavitation, and the high-strength aluminium bronzes compared favourably with the best of the high-strength alloy steels in so far as erosion was concerned. Other classes of material examined included various grades of iron and alloy steels. No specific recommendations are made in regard to the materials best suited for use in turbines, pumps, and similar equipment, but a very full discussion of the conclusions to be drawn from the investigation is given.

The author points out that cavitation resistance scales alone are not reliable, but must be correlated with comparative data relating to the corrosion and electrolysis behaviour of the materials in the particular fluid under consideration.

* S. L. Kerr. Trans. Amer. Soc. Mech. Engrs., LIX., 5, pp. 373-87.

The Application of Modern Microscopes in Metallurgy

By Dr.-Ing. A. SALMONY

Developments in the design and applications of the microscope have facilitated the investigation of metals and alloys, and in this article the author describes some of the modern instruments and discusses advances in the technique of microscopy in relation to metallurgical research and in routine applications.

Fig. 1.—English projection microscope, Vickers' design.

IN post-war years physical methods of investigation for testing materials—*e.g.*, by means of X-rays or δ rays (the so-called investigation of coarse and fine structure) have supplemented the older chemical methods and have attained considerable importance. Microscopical investigation, introduced into the industrial laboratory from the Research Institute, has taken a leading position, and observation in reflected light is now recognised as essential in metallurgy. All efforts in the development of the technique of microscopy necessarily aimed at simplifying and facilitating photomicrographs and adapting the methods of illumination to the particular requirements of the industrialist. The optical and mechanical system of the microscope itself, after the inventions of Abbe and the development of optical glasses by Schott had reached a certain perfection, and only during comparatively recent years have important changes been made.

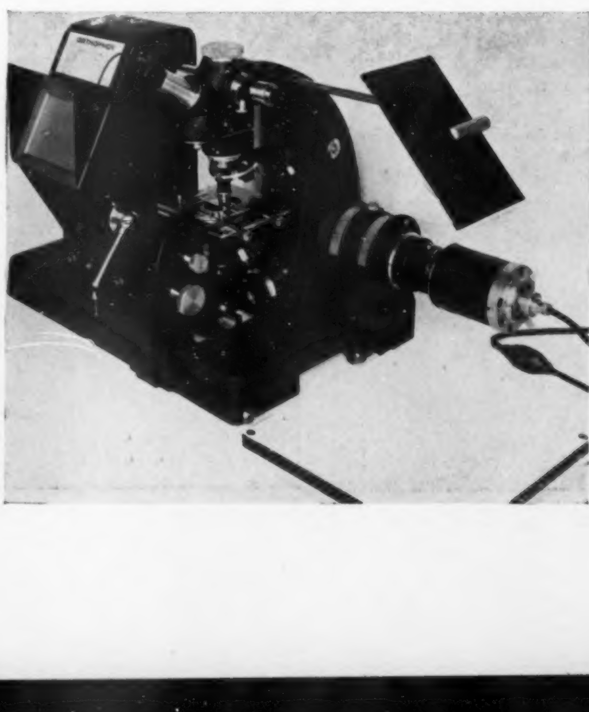
Only a few years ago the taking of satisfactory microphotographs was a prolonged and troublesome task. The microscopist often had to use such instruments as the older type optical bench, whilst the lengthy passing from one method of illumination to another was not at all satisfactory for industrial laboratories. For instance, the opaque illuminator of Kley and Florence, the Lieberkühn mirrors, and other illuminating devices, were not such as to make quick and convenient manipulation possible. Therefore, considerable advance can be said to have been made by the evolution of the so-called *camera-microscopes*, which comprise a complete research microscope, a camera attachment, and equipped with considerably improved illuminating devices.

Various patterns followed in quick succession, the English Vickers' design known as projection microscope model II, the Austrian MeF—Universal-Kamera-Mikroskop, the German instruments Neophot, Ultraphot, Panphot, Metaphot, and Orthophot. The English instrument is shown in Fig. 1. A comparison of the designs shows a certain degree of conformity. Generally the eye-piece tube is now arranged obliquely to the microscope tube at the ocular height of the observer. The connection of camera to microscope has been effected in various ways. Some models have the camera built into the pedestal of the instrument, which makes it necessary to dispense with the customary microscope pattern, because the nose-piece for the objectives had to be fitted underneath the object stage. This model has the advantage that prepared specimens can simply be laid on the object stage without troublesome arrangement by means of the specimen press. The point of gravity of this apparatus is fairly low, so that the stability is increased.

Increasing refinement is apparent in the later instruments. This applies to the "Orthophot," which, with its entire equipment is shown in Fig. 2. The problem of the most suitable connection of camera to microscope has in this case been solved in a novel way, the reflex camera being arranged on the left side of the microscope on a slide, so that it can be pushed back and separated from the microscope at any time, and a rigid connection has thus been avoided. To the right of the instrument, the device for projection and drawing is arranged. The image of the object can not only be projected on to the horizontal drawing board, but after removing the mirror, also to a vertical white screen erected at a distance of 0·5 m. from the apparatus. This device gives the advantage that results of investigation can be shown to a restricted number of persons without taking a micro-photograph. R. Fuess, of Berlin-Steglitz, in particular, has recognised the importance of using polarised light and has developed useful instruments. The resulting experiences have been applied in designing the special form of the "Orthophot" (Fig. 3A). Under the rotary object stage a polarising condenser is arranged, possessing an additional swing-out lens for convergent light, and larger magnifications. An analyser is built in to the tube. For visual observation, eyepieces with a large field of view can be used. The objectives can be centered independently and are inserted at the lower end of the tube by means of a special changer. The frequently used auxiliaries, such as microscope-refractometer, universal stages, integrating devices, etc., can easily be applied with this strongly built instrument.

An entirely new integrating device which facilitates preparatory work has been produced under the name of "Sigma," for scientific and applied petrography and also metallography. Its principle is electro-mechanical. Fig. 3B

Fig. 2.—"Orthophot," with complete outfit (R. Fuess, of Berlin-Steglitz).



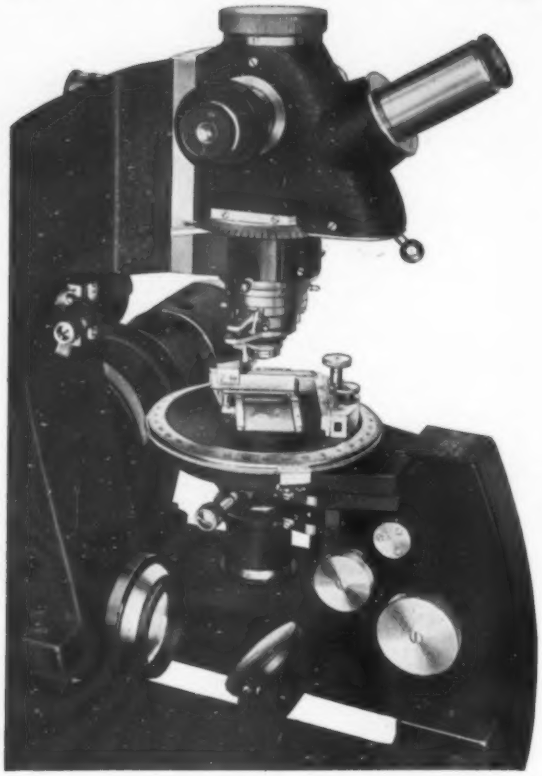


Fig. 3A.—*Central part of the " Orthophot," for work in polarised light.*

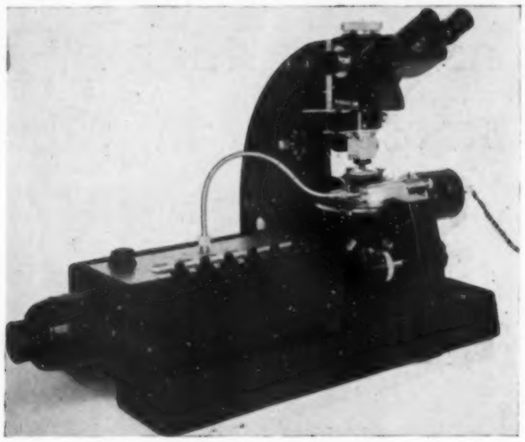


Fig. 3B.—" *Sigma* " *in connection with a microscope* (*R. Fuess*).

shows the instrument in connection with a microscope. The extraordinary advance made with this combination is particularly evident by a comparison with those technical auxiliaries which had to be used little more than two years ago by scientists—*e.g.*, as for petrography of coal.

The important question as to what is the value of the efficiency of modern microscopical technique can be answered by the statement that such instruments should permit convenient use without waste of time and furnish photo-micrographs with rich contrasts and sharp contours. By suitable selection of illumination all important particulars—*e.g.*, of prepared specimen, so frequently necessary in metallurgical investigation—can be made clearly recognisable without having to use large magnifications for which focussing and location of characteristic spots in the image are considerably more difficult than with relatively low magnifications. A few examples may explain this. Fig. 4 shows the photograph of a prepared specimen of copper pyrites and " Sanderz," in direct bright field, with 360 diams. magnification, a red filter being interposed by means of a pantolith plate, with 15 secs. exposure. Fig. 5 shows almost pure pearlitic grey-pig with single graphite particles in the structure. The photograph was made after etching the ground specimen with picric acid at 900 diams. magnification, a yellow and a bluish-green filter being inserted by means of a Perutz " Braunsiegelplatte " ; exposure 3 secs. Alloys with excellent wearing qualities can be obtained on the basis of cadmium by adding suitable hardeners. Experience has shown that a much higher load can be applied to such cadmium-bearing metals than to the white metals containing a high percentage of tin. Fig 6 shows the structure of a cadmium-bearing metal M 97, etched with 3% nitric acid, magnification 100 diams. Such an alloy has a melting point of 315° C., which is fairly high for low-melting metals. Fig. 7 shows a specimen of chilled white casting with 3·9% carbon at 900 diams. magnification ; 1·5 secs. exposure with yellow-green filter. The prepared specimen is etched with picric acid. Many similar examples could be given, but readers of this journal are familiar with excellent photo-micrographs which have been frequently reproduced in its pages.

For modern lighting, low-voltage incandescent lamps are commonly used. For most photographs in metallurgical laboratories, the 30-watt or one-filament lamp is sufficient. A stronger and more uniform illumination of the whole field of view is made possible by the 50-watts or two-filament lamp. Only in those cases where objects have many very fine characteristics to be strongly magnified need D.C. arc lamps of 4·5–6 amperes be used. When investigating different modern corrosion protectives with regard to their composition and to their behaviour on steel surfaces, the fluorescence analysis will be preferred, with the aid of an arc lamp possessing special electrodes or the customary analysis quartz lamp in a special pattern. In this case various parts of the optical system of the microscope must be replaced by glass permeable to ultra-violet rays.

Among the modern illuminating methods which are of importance for microscopical investigation in mining

Fig. 4.—*Photomicrograph of a ground specimen of copper-pyrite and " Sanderz."*

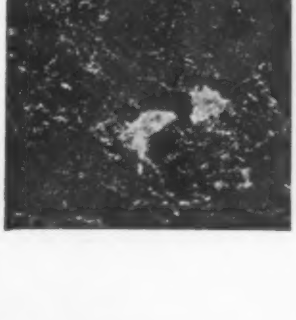


Fig. 5.—*Photomicrograph of pearlitic grey-pig.*

Fig. 6.—*Photomicrograph of cadmium bearing-metal.*

Fig. 7.—*Photomicrograph of chilled white casting.*

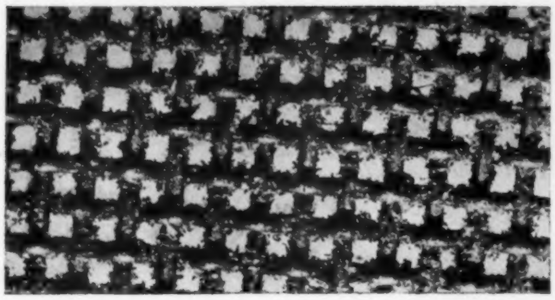


Fig. 8.—Wire net in Hauser illumination.

plants, smelting works, etc., the reflected and direct light illumination as indicated by Hauser deserves special mention. The principle of this method is to illuminate the ground mass of the object sufficiently to get the contours sharp. The simultaneously applied reflected light furnishes clear-cut images rich in contrasts, that cannot be obtained by any other procedure. Fig. 8 shows a specimen of a wire net photographed in this illumination at a 28 diams. magnification.

Of late, a so-called material microscope has been designed which is shown in Fig. 9 and is specially suitable for the surface investigation of materials. It has been so designed that the tube of the microscope can be moved freely in order that the objective can conveniently be directed to normally inaccessible parts of a larger body, to re-entrant edges, inside walls of cylinders, bottom faces of rail-heads, etc. In order to simplify the application, the illuminator with the source of light is rigidly connected to the tube, so that it follows all movements of the latter in focussing. The pedestal is removable, can be turned through 180°, and again be connected to the supporting rod of the microscope in order that round parts, such as specimens of tubes, screws, bolts, etc., can be placed into a V-shaped groove. The ability to adjust the tube vertically on the supporting rod permits putting even rather thick objects on the stage. After removing the pedestal the microscope with the supporting rod can be fixed to a larger base-plate, with photographic outfit (Fig. 10), comprising a vertical camera attachment with extensible bellows.

The modern machine for preparing specimens is a simple apparatus. It works with interchangeable grinding and polishing discs, including a great variety of materials, among which are paraffin discs of 200 mm. diameter, which are particularly suitable for fine grinding. The speed of revolution of the discs can easily be regulated by means of a three-step gear. Recently, entirely satisfactory polishings of soft lead have been obtained by suitable mediums.

It is imperative always to use the best plates for all photomicrographic work. For the majority of metallographic work the very fine-grained process plates are recommended, because their fine grain permits large magnifications in printing without loss of quality of the image. These kinds of plates are sensitive to blue, and therefore require a blue filter. They also must be nonhalation. In the case of many photographs of prepared specimens, the medium sensitive orthochromatic plate with properly selected filters are suitable for reproductions with good tone contrasts. High sensitive plates for taking instantaneous photographs are only to be preferred in rare cases—*e.g.*, for observation of an etching or of the course of a quick analysis of corrosion. Of great importance is the use of the most appropriate developer for each type of plate. In no circumstances can the various kinds of plates be treated with the same developer. So the careful microscopist will always use the developer which has been tried out and recommended by the platemaker.

The advance of the technique of microscopy will certainly be increasingly recognised in metallurgy, especially in its more direct contact with the industries in which metals are principally employed. The new investigation and auxiliary methods of microscopy will facilitate the better use of raw materials and further improve the materials of construction.

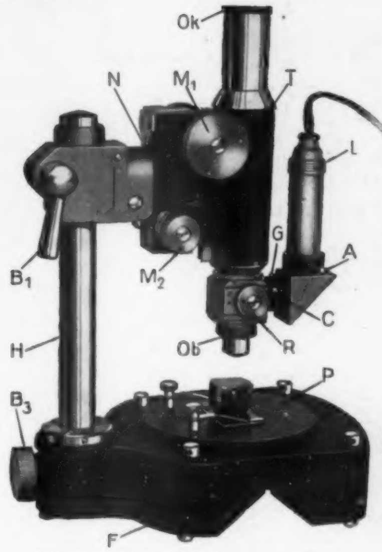


Fig. 9.—Material microscope, Fuess design.

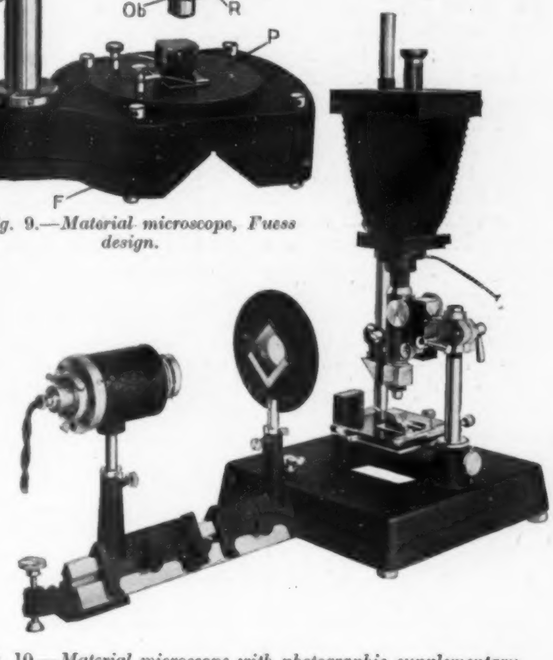


Fig. 10.—Material microscope with photographic supplementary outfit.

REFERENCES

K. Fischer. "Optik und Mechanik am modernen Mikroskop." *Zeitschrift fur Instrumentenkunde*, Nr. 4, S. 145 u.f., 1935.

Prof. Dr. Cohrs. "Mikrophotographie oder Zeichnung Blätter f. Untersuchungs-u." *Forschungsinstrumente*, 10. Jahrg. Nr. 3.

Comandon. "Un nouvel appareil de micro-cinématographie." *Recherches et Inventions*, No. 182, S. 302, 1929.

K. Laubenheimer. "Mikrophotographie und Mikroprojektion II." *Aufl. Verl.* Urban and Schwarzenberg, Berlin und Wien S. 176/177, 1931.

A. Kufferath. "Die neuzeitliche Mikroskopiertechnik im Dienste der Korrosionsforschung." *Korrosion und Metallschutz*, Nr. 7, S. 171, 1936.

F. L. Kühlwein, E. Hoffmann u. E. Kürpe. "Stand der mikroskopischen Kohleuntersuchung." *Gluckauf Heft* 34/35, *Seite* 777, etc., 1934.

Expansion in Canada's Radium Industry

The development of the radium industry at Great Bear Lake is one of the triumphs of modern mining. Discovery of important deposits of pitchblende, the chief commercial ore of radium, associated with rich silver ore, was made in 1930, but it was not until the latter part of last year that development and research had reached a point at which it could be stated with assurance that radium as a Canadian industry was established on a regular production basis. To obtain this status much progress had first to be made in four separate fields—mining, transportation, refining, and marketing. Radium production, as reported at the close of the year, is now on a scale of 2·5 grms. per month. In November last the Eldorado Gold Mines, Ltd., reported the completion of the recovery of its first ounce (28·35 grms.) of radium.

Medical science looks to the North-West Territories as an important source of one of its most effective weapons in the war on cancer, and the general programme of expansion now in progress in Canada's radium industry is of worldwide interest.

Roller Bearings in Mill Housings and Gear Boxes

A report by Carl Fläschel recently presented before the Rolling Committee of the Verein deutscher Eisenhüttenlente deals with the experience of the author on the question of mill bearings at the iron and steelworks of Neunkirchen (Saar). In this article the report is briefly reviewed.

FROM time to time the economical advantages of roller bearings are stressed, and their application to mill plant in particular has been favourably considered ; a recent report* on this subject is therefore of considerable interest. The report refers to roller bearings in the end housings of finishing trains of wire rod, bar and strip mills, and in various mill gearboxes at the iron and steelworks of Neunkirchen (Saar). In the finishing mills these have replaced lignum vitæ or green metal bearings, in the gearboxes white-metal bearings.

The reason for the change in the finishing rolls was the wish to increase the output of the mill per hour. This was possible only by rolling more lines at the same time, which was limited with the old bearings on the one hand by exceeding the tolerances of the products, and on the other hand by the driving power of the existing motors. For example, it was found through time studies at the wire-rod mill that the output could be increased from 12·5 tons to 20 tons and more, if it were found possible for the finishing train to produce wire of sufficiently uniform gauge despite the heavier loading. Similar calculations could be made for the bar and strip mills.

At the mill gearboxes three reasons facilitated the decision : the short life of the white metal and the resulting frequent delays ; the short life of the pinions caused by these plain bearings, and the saving of power with the roller bearings.

The report then gives details of the construction of the roller bearings and of the methods of their installation and dismantling, all of which, although highly interesting, cannot be dealt with here, owing to lack of space. In order to find out the economical results of using roller bearings the following points are then discussed individually :

(*a*) The first cost of the various bearings in mill housings ;
(*b*) The first cost of the bearings in the gearboxes ;
(*c*) Roll-changing costs ;
(*d*) Lubrication costs ;
(*e*) Cost of the rolls themselves ;
(*f*) Costs of electric power ;
(*g*) Costs of rejects resulting from the less exact rolling with plain bearings ;
(*h*) Differences in costs resulting from higher outputs with roller bearings.

Here it is only possible to give the comparison for the wire-rod mill, and as the figures are obviously valid only for the plant under investigation, and cannot be used for other plants operating under different working conditions, no attempt has been made to convert the German figures into English figures. They are " pfennig " per ton of rolled product, and so far as production figures are concerned, they are the result of careful statistics and investigations carried out for some months before and after the installation of the roller bearings. In doubtful cases figures unfavourable for the roller bearings were always taken, so that the final result is certainly on the safe side.

From this the whole investigation can be summarised, thus : In the first place, it is necessary to consider all the various points which may influence matters before deciding to change from plain to roller bearings. In the case in question the installation of roller bearings would have been uneconomical had not the greater output, or the decrease of production costs as result of greater output, given special advantages ; for the saving of electric current is more than counterbalanced by the higher first costs, the costs of roll changing, of lubrication and of the rolls themselves. If it is not possible to take advantage of the increase of output, the limit of economy of roller bearings is in most cases given by the increase of the changing rolls on the one hand, and by the decrease of the costs of the electric current on the other hand ; the latter may be preponderant, if it is possible to make big reductions in the passes.

This conclusion will hold, even more so, if one compares roller bearings with bearings of artificial resin, instead of with bearings of lignum vitæ ; for synthetic-resin bearings have even lower first and power costs than lignum vitæ bearings, and, moreover, they do not have higher costs of roll changing, of lubrication and of the rolls themselves, as is the case unavoidably with roller bearings. Also it is easier to obtain a greater accuracy with synthetic-resin bearings than with those of wood.

This question may be different with roller bearings at cogging mills, where roll changing is seldom necessary ; naturally, it must be presumed that the life of the roller bearings is long enough. It would be important in this case to have a comparison of roller bearings and synthetic resin bearings built on statistical figures over a period sufficiently long.

Economic Results

Costs.	At the Finishing Rolls.		At the Gear-boxes.	
	Plain Bearings, Pfennig/Ton.	Roller Bearings, Pfennig/Ton.	Plain Bearings, Pfennig/Ton.	Roller Bearings, Pfennig/Ton.
First costs	2·3	3·1	0·4	0·2
Roll-changing costs	0·5	4·5	—	—
Costs of lubrication	0·5	0·6	3·4	0·3
Costs of rolls	8·1	10·2	1·4	0·2
Costs of electric current	30·6	25·8	?	?
Costs of rejects	48·0	—	—	—
Production costs (dependent on output per hour)	260·0	—	—	—
Total	350·0	44·2	5·2	0·7
Success of roller bearings	305·8		4·5	

The saving through using roller bearings in gearboxes is not so important if the cost figures alone are taken into account, but it can certainly be strongly recommended from the production point of view as many delays formerly frequent may thus be avoided.

The saving of electric current has not been separately determined at gearboxes ; it is contained in that shown for the finishing housings.

* Report of Carl Fläschel at the Rolling Committee of the Verein Deutscher Eisenhüttenleute. *Stahl und Eisen*, vol. 37, No. 24, June 17, 1930.

New Honours Degree Course in Metallurgy

A NEW Honours Degree examination in Metallurgy has been established at Cambridge University, and the courses associated with this degree will commence in October next. The examination forms an additional Part II of the Natural Science Tripos, and is open to candidates who have already obtained honours in one of the Honours Examinations of the University. Normally, candidates will study for two or three years and take either Part I. of the Natural Science Tripos or the Tripos in engineering subjects. The subsequent metallurgy courses will require a further one or two years' study.

The new course arranged for this Honours Examination will include lectures by Professor Hutton, Dr. D. Stockdale, Dr. U. R. Evans, and Dr. Constance F. Elam. Courses in X-ray structure and physical chemistry will be included, together with laboratory instruction in the metallurgical and engineering laboratories.

The Melting of Grey Cast Iron in Different Types of Furnaces*

By S. E. DAWSON

Various factors which influence the character and properties of cast iron were briefly discussed, with particular reference to the method of melting employed, in the last issue, and attention directed to the advantages and disadvantages of the cupola. For this, the concluding part of the article, crucibles and rotary furnaces are discussed.

Crucible Furnace

BRIEF mention only will be made of the crucible furnace. Its value lies in the fact that the metal is not in direct contact with the fuel, so that special compositions and expensive alloy cast irons can be made with exactness, and comparative freedom from gas is obtained with obvious advantages. The cost of melting cast iron in the crucible furnace is considerably higher than for other types of furnace—coke, for example, —melting little more than its own weight of iron, and the upkeep in crucibles being also a contributory factor.

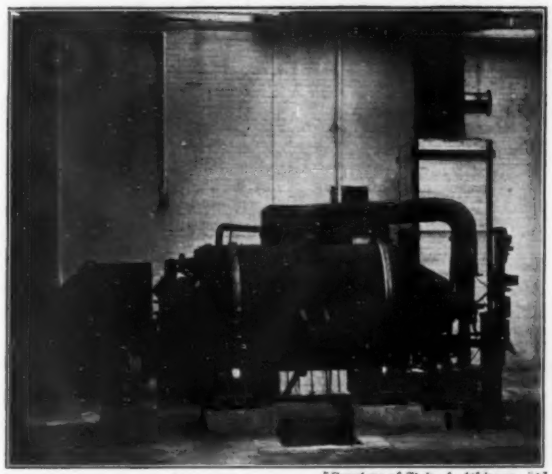
Certain modifications of the structure of cast iron may be brought about by the order of adding the raw materials, for example, steel will refine the graphite, whilst ferro-alloys will coarsen the graphite, if such additions are made at the end of the melt. The first heat may take as long as three hours, though later heats may be reduced to 1½ hours, depending on the character of the charge. The melting costs, exclusive of the metal, may vary from 55s. to 90s. per ton, according to the size of furnace and other considerations.

Rotary Furnaces

The design and construction of the different types of rotary melting furnaces now in use are somewhat similar, any variations being in respect of the manner or means adopted to burn the fuel, and the utilisation of the waste heat for the purpose of raising the temperature of the air of combustion in order more efficiently and rapidly to burn the fuel. The furnace body, the overall length of which is generally about 2½ to 3 times the diameter of the shell, is tapered at both ends, and the metal bath is situated in the centre. Two tapping holes are usually provided, one in either side of the furnace body, to obtain more even wear on the lining by their alternate use.

The main factors to be observed in the design of such a furnace are the rate of input of heat in relation to the size of metal bath, and the mass of refractory lining material in which to collect such heat for transference to the metal. In a suitably designed furnace the amount of fuel required for a given weight of metal follows the standard requirements of raising the cold charge to melting point and superheating the molten metal to the desired degree. The efficiency of the absorption of heat by the refractory lining, and by the air of combustion passing through the preheating system, is important in considering the heat balance of the furnace. It is found in practice that a suitable mass of refractory for heat transference is obtained by a lining thickness of about 2 in. for each foot of shell diameter.

For supplying a multiplicity of small castings, the intermittent operation might be a disadvantage unless the casting arrangements were so organised to take supplies from a ladle or receiver into which the whole bath had been tapped, so that the furnace can be recharged without delay. As the size of the castings increases, however, this problem becomes less difficult, since the number of moulds ready at one time are less, and an intermittent supply is often more convenient. The rotary furnace is made in sizes of



[*Courtesy of Stein & Atkinson, Ltd.*

One of the many types of rotary furnaces used for cast iron

1 to 15 tons capacity, and a close study of the size and rate of production of moulds must be made before the size of melting unit or units is decided upon.

When exact precision in analysis is required, as, for example, in chill rolls, steels, wear-resisting castings, and alloy irons, the metal can be held in the furnace whilst being sampled and analysed prior to making final adjustments in composition which may be found necessary. The character of burner employed depends on the type of fuel used, and in each case these have been developed to a high degree of efficiency by the various furnace-makers concerned.

Where a battery of furnaces is in operation, a central mill delivers the coal supply to the hoppers in rotation, or as required. The air preheater or recuperator, situated in the exhaust flue, is generally of the tubular type, the tubes themselves being made of specially treated steel, to withstand the temperature of waste gases in the flue. Appropriate gauges for recording the air temperatures and pressures are installed to allow constancy of operation and efficient working of the furnace.

The rotary furnace may be fired with either oil, pulverised coal or gas. Where oil is used, this is of the fuel-oil type, with a specific gravity of about 0·92. To maintain a constant pressure to the burner, the oil is supplied from an elevated service tank fed from the main storage tank. The fuel consumption is generally about 15 to 20% of the weight of metal melted, inclusive of heating from cold, emptying and slagging the furnace, and running at east three melts a day.

Where coal is the source of heat supplied, the kind used depends upon the type of furnace to be operated. In the closed type, where all the primary air is supplied with the powdered fuel, the mixture passing through and burning on a grid, somewhat on the principle of the gauze on a Bunsen burner, anthracite or semi-anthracite coal is used,

* Continued from July Issue.

but where complete combustion relies on a source of secondary air entering round the burner as in the open type, the coal may be of a bituminous soft quality.

The speed and efficiency with which powdered coal will burn depends mainly on the size of the particles, the temperature of the mixture of air and coal, and the percentage of volatile constituents present.

For a given size of particle the other two factors are dependent on each other, and for immediate ignition as required in the rotary furnace the following figures show the relative temperatures for a range of pulverised coals normally available: 7% volatile in the coal requires a temperature of 550° C.; 10% requires 460° C.; 13% requires 400° C.; 15% requires 330° C.; and 18% requires 260° C. Bituminous or soft coals containing 30% or more of volatile constituents will, of course, burn at once with cold air. In a rotary furnace, therefore, where the heat in the waste gases is not utilised, only soft coals can be used.

These temperatures are within the range of those obtainable from the waste gases, and relate to coals which have been so pulverised that 75 to 85% will pass through a 200-mesh, a degree of fineness imposed by the practical limitations of economic production. Beyond this degree of fineness the above temperatures of the volatile contents could be reduced and still give immediate ignition.

When once the dampers are set, the position of the flame relative to the burner or grid tends to adjust itself to the position as set. A flame burning too far along the furnace produces a high flue temperature, which raises the air temperature and therefore the speed of ignition, and automatically withdraws the flame again to the burner or grid.

The close control and intimate admixture of both the air and fuel supplies allow a near approach to theoretical combustion, so that a minimum oxidising atmosphere can be maintained in the furnace. The amount of air required to burn both the carbon and volatile matter in average suitable coal is 135 to 140 cub. ft., or about 10½ lb. by weight, and any excess over this absorbs heat from the flame and should be avoided.

Lining a Rotary Furnace

The selection of a suitable lining for the rotary furnace has been the subject of much thought and experiment. The conditions are more severe in this type of furnace than in the cupola, not only on account of the higher temperature attained, but also due to the more direct abrasive action of the charge, and of the fuel and air stream entering the furnace, and direct contact between the molten metal and the refractory. Whether bricks or a rammed monolithic lining be used, much care has to be exercised in their application, and since thermal expansion occurs in all siliceous refractory materials, suitable provision must be made to allow this to take place, both gradually, to avoid spalling, and within the mass of lining itself, to avoid damage to the shell of the furnace. In monolithic linings, internal expansion can be largely provided for by a suitable density of material, as controlled by the degree of ramming and the moisture content.

Many ganisters have been recommended for use in the rotary furnace with varying success, and whilst an ultimate composition of about 88% silica, 8% alumina, and 1% oxides, with loss on ignition as balance, seems to be the desirable basis, the number of heats given by such a material is influenced by the physical characteristics, such as grain size and the type or nature of the clay present.

Although many data are still lacking to establish the more exact effect of grain size in this connection, it is probable that the best results would be obtained with material approximating to the following sieve tests :—

	%
Retained on 30 mesh	20–25
" 60 "	40–25
" 90 "	15–10
" 120 "	55–10
Passing through 120 mesh	20–10

A suitable density to avoid undue internal disturbance during fritting and in service is about 2·3. A suitable moisture content is 6 to 8%, preferably added on site to the dry material as received, by sprinkling water through a rose on to successive inch layers until the desired quantity of refractory is laid down. After leaving to mature for three or four days, suitably covered to avoid evaporation, the mass is cut sectionally and relaid in a similar manner, water being sprinkled on between each 2-in. layer. Further maturing for a few days should be allowed before use, when almost maximum strength will be attained.

Experience is necessary to ram to the desired density, and it is generally advisable to feed the material under the rammer somewhat lighter near the shell of the furnace to allow expansion to be taken up and to facilitate the passage of steam to vent holes provided in the shell.

The internal shape and size of lining is controlled by sectional formers suitably bolted where necessary to permit of removal in parts after use. After air drying, the lining is dried by hot air or coke, an operation to be extended over several days or longer if possible. To avoid undue haste in these operations, the provision of a spare or duplicate furnace body is essential. Initial fritting of the lining prior to use for melting should be as slow as possible, in order to avoid spalling and possible internal disruption. Such precaution is specially important up to about 500° C., when the main expansion has taken place.

The general wear of a lining in service can to some extent be counteracted by repeated additions, between heats, of siliceous material or powdered recovered refractory, preferably in intimate admixture with small coal. Where more localised holes or depressions are concerned, patching with new material is necessary after chipping-out, to ensure good contact and substantial thickness, well keyed at the outer edges of the patch.

By careful attention to the foregoing points, it is possible to obtain as many as 300 heats from an individual lining when melting grey iron, although owing to the many factors involved, an average of 200 to 250 may be considered good practice.

Exclusive of the first heat from a cold furnace, metal may be tapped in about 2¼ hours after charging, varying from 2¾ hours for malleable tapping at 1,500° C., and 2 hours for grey iron at 1,450° C. Low-carbon irons and steels may take rather longer, and oil-firing tends to reduce these times. To the first heat an additional time of about 1 hour must be added for heating up the lining and flues.

Freedom from Slag Inclusions

The absence of internal reactions in rotary furnace metal and greater freedom from slag inclusions contribute to preserve the greater fluidity and refinement of structure, a feature of cast iron which allows of wider range of composition to meet the required physical properties, with distinct advantages in foundries making many types of castings.

The amount of FeO in the slag is usually below 2%, and this limits the reactions taking place between the slag and such oxidisable elements in the bath, as silicon, manganese, so that such losses are lower than when a higher oxidising slag is present.

As in other types of furnaces, however, such oxidation as may occur during the melting-down process varies somewhat with the nature of the materials charged, but the losses are in general less than those experienced in the cupola, whilst the carbon is controlled with reasonable precision.

Where more than one furnace is operated, some of the labour is spread over a larger tonnage, also special considerations may control the cost of fuel employed, whilst supplies of raw materials available, type of castings made, and different methods of computing costs also influence the figure.

Where higher temperatures are concerned, as in melting of malleable cast iron, this number is somewhat reduced, and where steel only is melted may fall as low as 50. Up

to the present, acid linings only have been used in practice, although some attention has been given to the possible use of a basic lining, suitably insulated from the shell to overcome the greater heat conductivity.

Assuming a single unit in each case, and stating the costs on the basis of a ton of molten grey cast iron at the spout, the following figures, exclusive of overhead charges, may be considered as representing average melting practice :—

	s.	d.
Refractory lining at 80s. per ton and 200 heats	2	0
Labour	2	9
Power at 0·75d. per unit	1	0
Maintenance	1	0
Limestone and sundries	0	3
Interest and depreciation	4	0
	11	0

To this must be added the cost of fuel in each case. These are calculated on the approximate rates per ton and ratios of fuel to metal melted as follows :—

	s.	d.
Bituminous coal (pulverised), at 20s. per ton and 18% ratio	3	7
Anthracite coal (pulverised), at 24s. per ton and 18% ratio	4	4
Fuel-oil at 80s. per ton and 15% ratio	12	0

The total costs are therefore :—

Pulverised coal (average 4s.) ....15s. per ton of metal melted.
Oil ....23s. " " "

It will be understood that in general the melting costs will be somewhat heavier for the smaller furnaces and lighter for the larger units, but such differences may be offset by the conditions prevailing at each furnace, depending on the tonnage output obtained—that is, the number of heats made per day continuously.

The above average costs assume an output of three heats per day or fifteen per week, although four heats per day could be readily maintained. Since these costs do not include the metal, it should be realised that considerable reduction in cost may be shown in cases where cheaper forms of raw material are available.

Variations in the Initial Corrosion Rate of Mild Steel in Chloride Solutions

RECENT studies of the electrochemical nature of the corrosion of iron in solutions of sodium and potassium chlorides indicate that initial corrosion rates vary, due to changes in the properties of the solutions. In dilute solutions the conductivity largely determines the rate of attack, and in more concentrated solutions the corrosion rate is limited by the solubility of oxygen. Experiments show that the cathode of the differential aeration cell, under half-immersed conditions, is polarised, whilst the anode potential is very little influenced by the corrosion current. The active cathodic area was confined to the proximity of the water-line on the specimen. The influence of both cation and anion have been investigated by Borgmann.*

Experiments were made to study the initial corroson rates of mild steel in a number of solutions of salts having a common anion. Cold-rolled strip steel (of 0·06% carbon, 0·32% manganese, 0·03% sulphur, and 0·016% phosphorous) was used. Specimens were cut from the strip, abraded with emery paper and placed in beakers, after which the beakers were placed in desiccators over anhydrous calcium chloride located in a large constant temperature air bath at 35° C. for 24 hours.

The test solution was prepared in advance, placed in the air bath for 24 hours, and then added to the beakers. The beakers were then placed in a second desiccator (over 3 N sodium hydroxide) for the 48 hours' test. The chloride content, oxide content, and hydrogen-ion concentration of the solutions were measured. At the completion of the test period, the specimens were washed in running water, loose corrosion products rubbed off with the fingers, and final traces of the products of corrosion were removed by cathodic treatment in citric acid.

Results showed that the cation has a marked influence on the corrosion rate of the metal. In aqueous solutions another cation, hydrogen, is always present and must be taken into account, although solutions with the same initial hydrogen-ion concentration give different rates of corrosion, depending entirely on the other cation present. The viscosity of the solutions may have some influence on the rate at which oxygen can reach the surface of the metal and accelerate the rate of attack, but these are not primary causes of the differences in corrosion rates. There is a close relationship between conductivity, in dilute solutions, and the corrosion rate ; yet this, too, should only be regarded as a contributory factor.

The main point elucidated was that the stronger the basic properties of the cation, the more rapid is the oxygen absorption type of corrosion and the smaller is the naturally formed or anodic area. The probability that attack will occur is less in the salts of the more basic cations and less pitting should be expected in solutions of alkaline earth salts than in those of the alkali salts.

Variation in the rate of change of cathode potential with the amount of total current flowing and in the potential of the cathode at zero current determine the rate of corrosion of iron. Possibly, the exchange of cations influences the cathodic polarisation rather than the magnitude of the static potential at the cathode. This appears to conform to the postulate of discrete " active " cathodic areas.

The greater probability of attack (increase in size of anodic area) as one passes from the alkali to the alkaline earth salts is due to a combination of two factors : (*a*) The rate of production of hydroxyl ions at the cathode is less (lower rate of corrosion), and (*b*) the bases thus formed are weaker in character. The alkali formed maintains the *p*H high enough in the alkali salt solutions to precipitate *in situ* any iron ions tending to go into solution over a fairly large area, but the hydroxides of the alkaline earths would be effective only over smaller areas.

The variation of the initial corrosion rate with concentration was measured for a large number of different chloride solutions. The order of increasing corrosiveness of the cations being as follows : Magnesium, cadmium, manganese, calcium, strontium, barium, lithium, sodium, potassium, aluminium, ammonium, chromic, and ferric. The rate of attack in neutral solutions was found to depend largely on the nature of the cation, as long as the anion formed a soluble primary product and was non-oxidising. An explanation, based on the assumption that the cathodic depolarisation takes place at discrete " active " points, was given. The cation was assumed to influence either the number of such points or their ability to aid the hydrogen-oxygen reaction.

The corrosion of iron in ammonium, ferric, aluminium, and chromic chlorides was found to take place largely with the evolution of hydrogen or with the reduction of the cation. The attack increased with concentration in all cases, and the presence of an oxidising cation increased the rate of attack. Ferric chloride was much the most corrosive of any salt tested. In most cases the first additions of a second salt had the most marked influence on the corrosion rate. The character and distribution of attack were also often influenced by the presence of a second cation.

* C. W. Borgmann, *Ind. & Eng. Ch.*, Vol. 29, No. 7, 814-21.

Correspondence

CAUSES OF TROUBLE IN HEAT-TREATMENT

Pyrometers and Recorders

The Editor.

Sir,—With reference to your contributor's remarks in the July issue, regarding pyrometers, under the above heading, it should be brought to your readers' notice that the errors referred to under heading B—viz., cold junction effect—should be non-existent in any modern installation. All reputable manufacturers are to-day supplying equipment embodying devices which compensate for fluctuations in cold-junction temperature automatically. When using such devices it is desirable, if complication is to be avoided, that compensating cable is used right up to the reading instrument, so that the cold junction is actually at the instrument. This involves a slight increase in the cost of the initial installation, and also makes it essential to use instruments having high internal resistance.

It must be agreed that your contributor's remarks regarding some old installations are fully justified, although, as he states, manufacturers will be found only too willing to assist by advising as to the best method to adopt to avoid errors of the kind referred to.

With regard to the apparent lack of knowledge among furnace operators, regarding pyrometers, it may be of interest to your readers to know that we have, in booklet form, reprints of two articles* which appeared in your journal, which we shall be only too pleased to forward to any interested person.—Yours, etc.,

Electroflo Meters Co., Ltd.,
A. Wright,

July 20, 1937.

*[The articles referred to by Mr. Wright are "Fuel Fired Furnace Temperature and Atmosphere Control," reprinted from the December, 1934, issue, and "The Installation and Maintenance of Thermoelectric Pyrometers," reprinted from the June, July, and August issues of 1935.—Editor.]

The Editor.

Sir,—We have read with interest the contribution by "H. T.," printed on page 78 of your July issue, dealing with pyrometers and recorders, under the heading, "Causes of Trouble in Heat-treatment." Without doubt, there are many cases where the full benefits accruing from the use of pyrometer equipment are not obtained, due to the lack of knowledge on the part of the user, of the fundamental principles of the various types of temperature-measuring equipment.

The position is improving steadily as apparatus tends to become more foolproof, and as the wide importance of the pyrometer becomes better recognised, qualified staff are made responsible for the use and upkeep of the instruments.

We have long recognised the need for a better knowledge of the principles of pyrometry on the part of the user, and for many years we have published not only a list of our manufactures, but a separate theoretical section dealing with the technique of the particular class of instruments covered, copies of which are available on request.—Yours, etc.,

Foster Instrument Co., Ltd.
J. F. Martin.

July 28, 1937.

The Editor.

Sir,—In reading your last issue, it is observed that your correspondent, "H. T.," is again in the news, this time stirring up the mud in the heat-treatment shop. While the complaints outlined are clearly justified, and while all are remediable there are several sources of inaccuracy in pyrometer installations which have not been mentioned. Not the least of these is dirty connections. Before passing to this question, however, the questions raised by "H. T." need more detailed consideration.

As pointed out, incomplete conceptions as to the underlying principles of pyrometry are largely responsible for many subsequent hardening troubles, and if your correspondent can be criticised as having a bee in his bonnet over the question of cold junction effects and corrections, his strictures are at least well justified in not a few instances. In a large number of hardening shops it is customary to set the zero reading of the indicating instrument to about 25° C. on the assumption that that is the temperature of the cool end of the thermocouple in its position at the back of the furnace. In other instances within my experience settings have been made at 40° and even 50° C., according to the temperature thought to be prevailing at the back of the furnace. This is, of course, a matter of individual judgment or guesswork, but whatever value is selected it must be pointed out that if a thermocouple is calibrated for a cold junction of t° C. and is then used at some other temperature, such as T° C., it is not correct to add the difference (T–t) to the indicated temperature in order to arrive at the proper temperature reading. Contrary to statements appearing in older text-books on pyrometry, this temperature difference has to be multiplied by a factor K, which depends chiefly upon the type of couple employed, and upon the temperature it is desired to read. Expressed mathematically, the correction is therefore K (T–t).

It will be clear that this correction can only be applied if the cold junction is not itself subject to fluctuations, such as may easily occur in the hardening shop. The value of the constant K may vary from 1·00 for base metal couples to 0·5 or less with rare metal couples, but having regard to the operating temperatures in most hardening shops dealing with steel components, and bearing in mind the degree of accuracy normally desired, the constant K may for all practical purposes be taken as 0·6 for rare metal couples, at 1·0 for base metal thermocouples.

In view of the need for periodic checking, it is good practice, according to the author's experience, to check each thermocouple once a week with a portable potentiometer and recalibrate once a month. It may possibly be argued that this is unnecessary, but in practice it is found to eliminate very largely errors in temperature control, and complaints as to the accuracy of thermocouple installations. Those who are not able or willing to undertake the monthly recalibration may, as an alternative, perform the weekly check suggested by experience, using standard tables, such as those issued by the instrument makers or the Washington Bureau of Standards.

Another source of trouble to which your correspondent has not referred, although he is probably aware of it, lies in dirty or faulty connections. These may commonly be found in the junction boxes employed where one indicating instrument serves a number of furnaces. The junction boxes are most frequently placed in a position on the wall at the back of the furnace and are usually neglected.

Faulty or dirty connections can be the cause of quite a lot of trouble, for they may render indicators both inaccurate and insensitive to changes in the temperature of the thermocouple hot junction in the furnace. This is particularly likely to happen with recorders of the potentiometer type, and is, of course, curable by regular inspection of all contacts in the wiring system. It was indeed the author's practice in controlling more than one hardening shop to insist upon connections receiving attention at each weekly checking.

In recording these experiences, it is hoped that troubles similar to those enumerated by "H. T." may be successfully overcome.—Yours, etc.,

W. F. Chubb.

Essex,
August 4, 1937.

Comparison of Methods for the Determination of Oxygen in Steel

Several plain carbon sticks and an open-hearth iron, using different melting and deoxidation practices, have been studied with the object of comparing methods for determining their oxygen content. A brief summary of the results is given.

A CO-OPERATIVE study of methods for the determination of oxygen in steel provided data from the reports of 35 laboratories, comprising more than 2,000 analytical determinations.* This study made available 15 reports of determinations by the vacuum fusion method, 11 by iodine methods, 8 by electrolytic methods, 4 by hydrogen reduction methods, 3 by the chlorine method, 2 each by the mercuric-chloride method and hydrochloric acid methods, and one by the nitric acid method.

The results indicated that the vacuum fusion method gives accurate results for the determination of oxygen contents of plain carbon steels, either aluminium-killed, silicon-killed, or of the rimming type ; the aqueous-iodine method gives accurate results for some types of killed steels, but that more data is necessary to define the accuracy of the other methods employed in this analysis.

Two main classifications of methods were thus used—" residue " and " reduction " methods. The first classification depends upon the action of a selected medium to separate the metallic portions of the sample from the oxygen-containing constituents, and includes the iodine, electrolytic, mercuric chloride, hydrochloric acid, nitric acid, and chlorine methods. The reduction methods depend upon the action of carbon or hydrogen at elevated temperatures, to reduce the oxygen-containing constituents. With the exception of the fractional vacuum fusion method, the reduction methods yield a single value for the sum of the oxygen contents, and do not attempt to identify individual oxides and compounds.

Seven plain carbon steels and one open-hearth iron were selected, as indicated in the accompanying table, different melting and deoxidation practices ensuring the presence in the steels of different amounts and combinations of oxygen. Alloy steels were not included, to avoid complication.

TYPE AND COMPOSITION OF THE SELECTED STEELS.

Steel.	Type.	Additions.			Composition (%).						
		Furnace.	Ladle.	Mould.	C.	Si	Mn.	S.	P.	Cr.	V.
1	Low-carbon, rimming	None	FeMn	None	0·03	0·002	0·31	0·036	0·011	0·004	<0·001
2	Medium-carbon, high-manganese, silicon-killed	FeMn	Hot metal, FeMn, FeSi	None	0·42	0·26	1·15	0·025	0·020	0·022	<0·001
3	Bessemer screw stock semi-killed	None	FeMn, S	FeSi	0·12	0·024	0·72	0·168	0·101	0·006	0·004
4	Special, low-carbon, aluminium-killed	SiMn, FeMn	FeSi, Al	None	0·17	0·09	0·65	0·029	0·014	0·008	0·001
5	Low-carbon, silicon-killed.	None	FeMn, FeSi	None	0·22	0·14	0·45	0·042	0·020	0·020	0·001
6	Medium-carbon, silicon-killed	Spiegel	FeMn, FeSi	None	0·43	0·20	0·47	0·027	0·014	0·012	<0·001
7	Open-hearth iron, rimming	None	Al	None	0·016	0·001	0·024	0·022	0·011	0·009	<0·001
8	Similar to No. 4, but higher in oxygen	None	Al	Al	0·20	0·03	0·45	0·033	0·014	0·012	<0·001

Vacuum-Fusion Method

The sample is melted in a graphite crucible contained in a highly evacuated furnace, occluded and dissolved oxygen is liberated and the various oxide and silicate combinations reduced. Determination of the amount of carbon monoxide in the evolved gases furnishes a value for the total oxygen content of the material, but does not differentiate between the different compounds of oxygen that may be present. The fractional vacuum-fusion method, however, allows values to be obtained for individual oxides by reduction of the sample in stages at successively increased temperatures, with separate analysis of the gases evolved in each stage. This latter method also allows the simultaneous determination of nitrogen and hydrogen, as well as oxygen, in a single sample.

Iodine Method

The sample is treated with a suitable solution of iodine ; iron, silicon, and manganese are dissolved, and a residue of unattacked oxides and carbonaceous material (carbides in certain cases) remains. One method is to use an aqueous solution of iodine in ferrous iodide, another is to treat the sample with a solution of iodine in anhydrous methyl alcohol, and a third is to use a solution of iodine in absolute ethyl alcohol and filter through an ultra-filter.

Hydrogen Reduction Method

Oxides are reduced in the sample by means of purified hydrogen at elevated temperatures, the amount of water vapour in the hydrogen leaving the furnace indicating the amount of oxides reduced. It is generally believed that FeO and MnO are completely reduced, and that refractory compounds, such as Al_2O_3 and certain silicates, are reduced only partially or not at all.

Electrolytic Method

The sample is made to anode in an electrolytic cell, the conditions of electrolysis are controlled, and the soluble metallic constituents are separated from the non-metallic material. The loss in weight of the anode is then determined, and the insoluble residue collected and analysed. Four different electrolytic solutions were used : (*a*) An aqueous solution containing 3% $FeSO_4$–$7H_2O$ and 1% NaCl ; (*b*) An aqueous solution containing approximately 45 g. magnesium oxide and 2 g. iodine per litre ; (*c*) A 3% aqueous solution of ferrous chloride ; but in some experiments a solution containing 3% sodium citrate and 0·1% ferrous chloride was used in the anode compartment ; and (*d*) A 0·1 N. potassium bromide solution containing approximately 10% sodium citrate for the anode compartment and a 10% solution of a copper salt, either sulphate or bromide, for the cathode compartment.

Mercuric-Chloride Method

The sample is subjected to the action of an aqueous solution of mercuric chloride, 120 g. per litre, in the absence of air, until the reaction, $Fe + 2HgCl_2 = FeCl_2 + 2HgCl$, is complete. FeO and MnO remain in the insoluble residue. Compounds of manganese and iron with phos-

* Journal of Research of the National Bureau of Standards, Vol. 18, 1937. Research Paper 976. U.S. Department of Commerce.

phorus, sulphur and nitrogen are not decomposed quantitatively, and the determination of SiO_2 and Al_2O_3 is not attempted.

This method consists of heating the sample for several hours at a moderate temperature in a stream of purified chlorine, thus converting the metallic constituents to chlorides, these being largely volatile under these conditions, but leaving the oxide constituents unattacked, and which can then be determined in the residue from this chlorination treatment.

The sample has tin added to lower the melting-point, and is maintained at four temperatures successively. It is assumed that the oxides in a steel can be separated according to the temperatures necessary for their reduction. FeO in steel can be reduced completely at 1,050° C., MnO is reduced at 1,170° C., SiO_2 at 1,320° C., and Al_2O_3 at 1,570° C. The sample is maintained at each of these temperatures in turn, and the amount of gas evolved at each stage is used to indicate the amount of the oxide constituents.

Metallic constituents are soluble in a 10% nitric acid solution, but oxides, and in particular alumina, are relatively insoluble. It must be noted, however, that some of the silicates that may occur in steel may be partially dissolved in the acid medium, and give low results for SiO_2.

The metallic and oxide constituents are separated by the use of dilute hydrochloric acid, using approximately two volumes of water to one volume of concentrated acid. SiO_2 and Al_2O_3 are determined from the insoluble residue, but this method is not applicable to the determination of FeO and MnO.

The vacuum-fusion method appears to yield the most accurate results for all eight steels; the aqueous-iodine method gives accurate results for aluminium-killed steels, the data for steels 1, 2, and 3, and to some extent 7, show that this method cannot be relied upon for determining the oxygen content of all steels; and none of the other methods can be approved or rejected as adequate until further data and experiment are forthcoming.

British Foundry School

THE second annual general meeting of the British Foundry School took place in Birmingham on July 27th. Mr. R. G. Hosking, chairman of the governing body, presided. The report and accounts, embodied in the Second Annual Report, were unanimously adopted, and the members of the governing body re-elected. Bendall, Denson and Co. were re-elected auditors.

At a subsequent meeting of the governing body, Mr. R. G. Hosking was re-elected chairman; Alderman W. Byng Kenrick, vice-chairman; and Mr. J. G. Pearce, honorary adviser and honorary treasurer. Other members of the governing body are Mr. G. L. Bailey, representing the British Non-ferrous Metals Research Association; Mr. John Belliss, Institution of Mechanical Engineers; Mr. W. R. Blair, National Light Castings Ironfounders' Federation; Mr. E. R. Briggs, British Cast-iron Research Association; Mr. W. E. Clement, Welsh Engineers' and Founders' Association; Mr. E. W. Colbeck, Imperial Chemical Industries, Ltd.; Mr. H. E. Cookson, Iron and Steel Institute; Mr. E. C. Evans, British Iron and Steel Federation; Mr. F. Hickinbotham, J.P., Birmingham Education Committee; Mr. J. E. Hurst, Institute of British Foundrymen; Mr. J. E. Montgomery, Institution of Mechanical Engineers; Mr. B. Pontifex, City and Guilds of London Institute; Mr. P. Pritchard, Institution of Automobile Engineers.

The following act as advisory members: Dr. D. S. Anderson, Principal, Birmingham Central Technical College; Mr. R. W. Blount, H.M.I., Board of Education; Dr. F. T. Chapman, H.M.I., Board of Education; Dr. P. D. Innes, C.B.E., Chief Education Officer, Birmingham; Mr. G. H. Rogers, Secretary, British Foundry School.

The Reliability of Some Thermocouples

THERMOCOUPLES are being used to an increasing extent in research work, laboratories, and analytical work, in addition to their regular industrial applications. It appears, however, that more knowledge can be gained as to the effect on the more commonly used types of such couples of certain conditions of treatment, and of what effect heating the thermocouples to different temperatures may have on their electro-motive force—temperature relationship.

Recent experiments have shown that a considerable number of chromelalumel thermocouples did keep within the guarantee limits fixed by the manufacturers, these being $\pm 2 \cdot 8°$ C. in the range 0° – 350° C. and $\pm 0 \cdot 75\%$ in the range 350° to 1,250° C.

Work has been undertaken by Quiggle, Tongberg, and Fenske* in regard to copper-constantant, copper-copel, and chromel-alumel couples, these couples being calibrated either at fixed points, such as the boiling points, freezing points, and transition points of pure substances, or by comparison with standard thermocouples. In the latter case a copper block was used as the source of heat, determining any desired number of points over a range of 0° to 450° C.

The results show that copper-copel thermocouples made from the same spools of wire (No. 30 B. and S. gauge enamelled copper wire) agreed within 0·1° C. up to a temperature of about 180° C., but that a copper-copel couple made from a different spool of copel wire reads 1·9° C. less than the standard copper-copel couple at 109·2° C. At this temperature of 109·2° C. the chrome-alumel couples made from the same spools of manufacturer's wire (No. 22 B. and S. gauge, asbestos covered) differed more from one another than did the copper-copel thermocouples; the copper wire being of high purity, making that half of the couple wholly reproductive.

It has also been shown that the vital part of a thermocouple is that along which there is a temperature gradient, that representing the part which mainly determines the calibration and constancy. If the thermocouple is always immersed to the same extent in the hot medium, and if the temperature distribution in the temperature gradient from the hot medium to the cooler medium is always the same, there is no change in the electromotive force-temperature relationship with heating and use even if the wires are not homogeneous over this section. However, it is seldom that the ordinary user of thermocouples—unless it be in some industrial process where units are run under fixed conditions—does not vary one or both of these important items.

The thermocouples which were tested had not previously been heated above 180° C. The copal wire had a composition of 55% Cu and 45% Ni, while the constantant wire consisted of 53·6% Cu, 44·4% Ni, 1·4% Mn, the remaining 0·4% being impurities.

The final analysis of the tests appears to indicate that heat-treatment of copper-copel, copper-constantant, and chromel-alumel thermocouples above 200° C. causes them to record temperatures different from those recorded before heat-treatment, the disparity in general increasing with the higher heat-treatment temperatures, and that copper-copel and copper-constantant thermocouples will indicate a higher temperature after heat-treatment between 200° C. and 300°–350° C. Copper-copel and copper-constantant thermocouples can be stated to possess a good degree of reliability when used in the temperature range of 0° to 200° C.

* D. Quiggle, C. O. Tongberg, and M. R. Fenske. *Ind. and Eng. Chem.*, vol. 29, No. 7, 827–30.

Porosity in Spraying Coatings and its Measurement

By

E. C. ROLLASON, M.Sc.

The application of metal-spraying processes is developing rapidly. One of the problems associated with these processes is the porous character of the coatings, and in this article the formation of the coatings is briefly described and a number of methods for measuring the porosity of the coatings are discussed

THE use of metal spraying has been increasing in recent years for the treatment of surfaces of the most varied kinds, with the object of either providing protection against corrosion and oxidation at elevated temperatures, building up worn articles, or producing an appearance more pleasing to the eye. At the present time three types of pistol, using wire, molten metal and powder, are used, but in all cases the deposits produced are always slightly porous. In certain applications such porosity is not a series defect. For instance, in the atmospheric corrosion of zinc coats on iron the products of corrosion tend to seal up the pores, and in any case the zinc is anodic to the base, with the result that a high degree of protection is afforded even when the coating is cracked. On the other hand, pores in a tin or copper coat on steel are a serious disadvantage.

In metal spraying, globules of molten metal are formed at the nozzle and are projected on to the object by means of an air blast. Whether a particle is still molten when it strikes the base will depend on the distance of the nozzle from the surface, but at normal spraying distances the particles are plastic. A possible sequence of events, based on the behaviour of splashes of solder, is illustrated in Fig. 1. On striking the surface the globule becomes thinner in the centre, and as the " wave " of metal moves outward the oxide skin is broken in places and the typical splash effect is produced. Frequently, owing to surface tension effects, holes are left in the centre portion. This is well illustrated in Fig. 2, which is a photomicrograph of two sprayed particles of copper on a glass slip. Reflected light is used, and the dark areas represent clear glass. As a result of this splash formation numerous pores are trapped between the individual particles. When the nozzle is near to the object, both the temperature and the velocity are sufficiently high to give good interleaving of the particles, and, while the density will be lower than a worked metal the inter-connected porosity will be small. When the pistol is held far from the object many particles are fairly rigid when they strike the surface with the result that a " heaped " sand-like mass is formed with a high connected porosity (permeability). These points are illustrated in Fig. 3 and Fig. 4. The latter shows the structure of sprayed

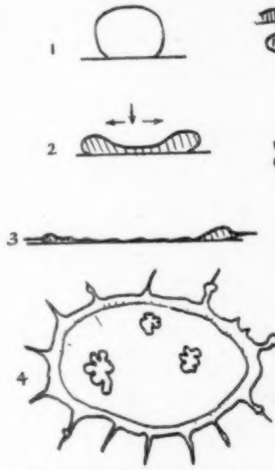


Fig. 1.—Diagrammtic illustration of the formation of a splash of molten metal.

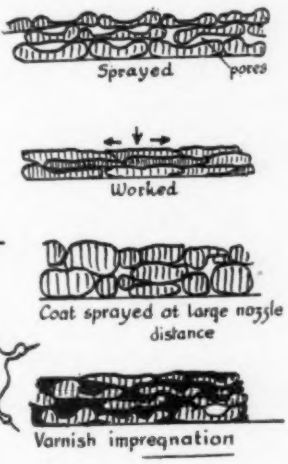


Fig. 3.—Schematic representation of porosity in sprayed coatings.

aluminium when using the pistol at an excessive distance from the object. The particles are practically undeformed, and exhibit a typical " cored " structure. The dark areas in the photograph are the pores. Fig. 5 illustrates the more usual laminated structure, with columnar crystals across each lamination indicating that solidification after the particle had struck the surface. The black areas indicate porosity. Comparatively little oxide is present in this sample, but it will be appreciated that in certain cases the oxides formed in spraying may partially fill the pores, and so reduce the porosity.

The measurement of porosity of sprayed coatings is somewhat difficult, but, in view of its interest, a number of methods are discussed below.

Measurement of Porosity

Rollason recently used the following method for estimating porosity : Built-up samples of sprayed metal, $\frac{1}{8}$ in to

Fig. 2.—Copper sprayed on glass—normal reflected light. ×50.

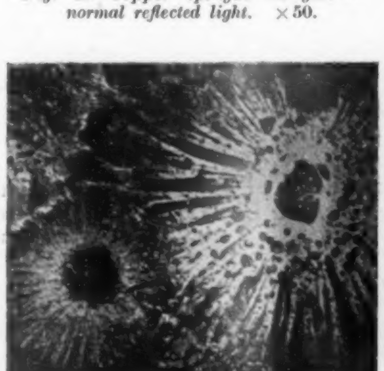


Fig. 4.—Sprayed aluminium, using great nozzle distance. Porosity = 34%. Cavities are black.

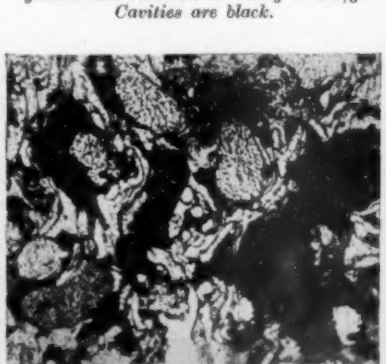
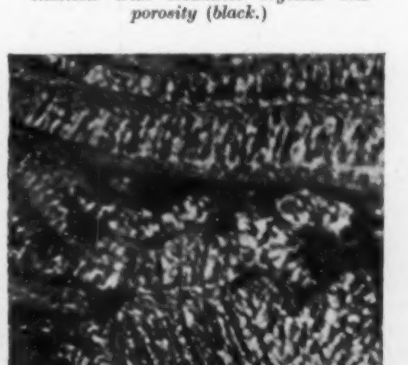


Fig. 5.—Normal sprayed copper. Laminations with columnar crystals and porosity (black.)



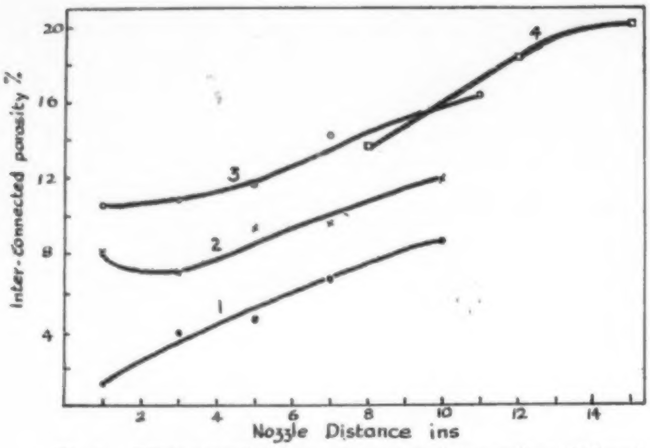


Fig. 6.—Effects of nozzle distance on porosity of zinc coatings (Rollason).
Curve 1, English wire pistol, coal gas.
Curve 2, English wire pistol, acetylene.
Curve 3, molten metal pistol.
Curve 4, powder pistol.

$\frac{1}{16}$ in. thick, were stripped from the base, weighed, boiled in toluene for one hour, and subsequently weighed suspended in toluene, the temperature being estimated at 0·1° C. The toluene penetrates the pores with great rapidity, and the specific gravity subsequently calculated is that of the metal, oxide and isolated pores. The samples were then heated under reduced pressure until the original weight was obtained (in order to drive off the toluene).

The specimens were next coated with a very thin film of vaseline (·02 to ·04 grm.), and weighed suspended in distilled water. The film of grease prevented the water from penetrating the pores, and enabled consistent results to be obtained. The difference between the two calculated specific gravities has been converted into percentage (permeable) porosity. Typical results follow:

Process and Metal.	Interconnected Porosity, %
English wire—	
Zinc, C.G.	3·9
,, Ac.	7·0
Tin	6·8
Copper	9·1
18/8	6·1
Steel	3·4
Lead	4·6
Molten metal—	
Zinc	10·9
Aluminium silicon	3·3
Powder—	
Zinc	13·8
Aluminium	15·6

The effect of the distance of the nozzle from the object on the porosity of zinc coatings is shown in Fig. 6. At very small nozzle distances the porosity is at its minimum, but it rapidly increases as the nozzle distance increases. This result is not unexpected, since at close distances to the nozzle the particles are sufficiently plastic to allow effective interleaving. At great nozzle distances the particles are cooler, more rigid, and have less velocity, consequently forming a loose, "heaped" structure. Unfortunately, with the usual design of nozzle the difficulties of operating at close distances are great, owing to the overheating of the deposit and also to its unevenness.

In Fig. 7 the specific gravities of sprayed zinc as found in water and in toluene are plotted against nozzle distance. For reference, line 1 is plotted for sound zinc. The difference between curves 2 and 3 can be used to estimate inter-connected porosity, while the difference between curves 1 and 2 indicates the extent of the isolated porosity neglecting the effect of oxide. In the samples under discussion the wire pistol produced specimens with low connected porosity but high isolated porosity, and for many applications the isolated porosity would have a negligible effect. The powder process has produced samples with high inter-connected but low isolated porosity. This is undoubtedly due to a large extent to the great spraying distance.

Ballard and Harris have made measurements of comparative porosity of sprayed coatings. Steel rod, $\frac{1}{2}$ in. dia., was mounted on a lathe and sprayed on the cylindrical face with $\frac{1}{8}$ in. thickness of metal, and left in the sprayed condition. Samples, 1 in. long, were weighed and immersed in a refined paraffin with a vacuum maintained above the oil for some days. After removal from the oil the samples were wiped dry with a clean rag, and re-weighed. The increase in weight is due to absorbed oil, and indicates the weight of oil which has penetrated into the inter-connected pores. Typical results follow :—

COMPARATIVE POROSITY FOR WIRE PISTOLS.
Weight of oil absorbed in grms.

Nozzle Distance, In.	Using Coal Gas.		Using Acetylene.		
	English.	French.	English	French.	American.
1	0·046	0·070	0·051	0·062	0·078
2	0·120	0·080	0·057	0·087	0·098
3	0·150	0·100	0·103	0·131	0·100
4	0·172	0·121	0·121	0·152	0·152
5	0·192	0·139	0·130	0·152	0·213
6	0·192	0·122	0·121	0·147	0·214
7	0·190	—	—	0·143	0·206
8	0·175	—	—	—	—
9	0·175	—	—	—	—

COMPARATIVE POROSITY FOR WIRE PISTOLS USING NITROGEN.
Weight of oil absorbed in grms.

Pistol.	Nozzle Distance.	
	1 in.	3 in.
English type using acetylene	0·042	0·082
French ,, ,,	0·055	0·162
American ,, ,,	0·097	0·136
English ,, coal gas	0·046	—

T. Everts* attempted to evaluate the porosity of sprayed metal coatings to air and water, and the effect upon the porosity of various experimental conditions.

The coating was sprayed on to a circular polished iron surface. The deposit was then removed and fitted as a membrane inside a pipe. Water or air under an excess pressure of one atmosphere was supplied on one side of the membrane, and the amount of the media penetrating the coating in a known time was measured. The apparatus was very similar to that used by Schoop.

The soundness of the coating was expressed as the number of seconds taken by 1 litre of gas to penetrate 1 cm.² of the coating (0·5 mm. thick) under an excess pressure of 1 atmosphere at 15° C.

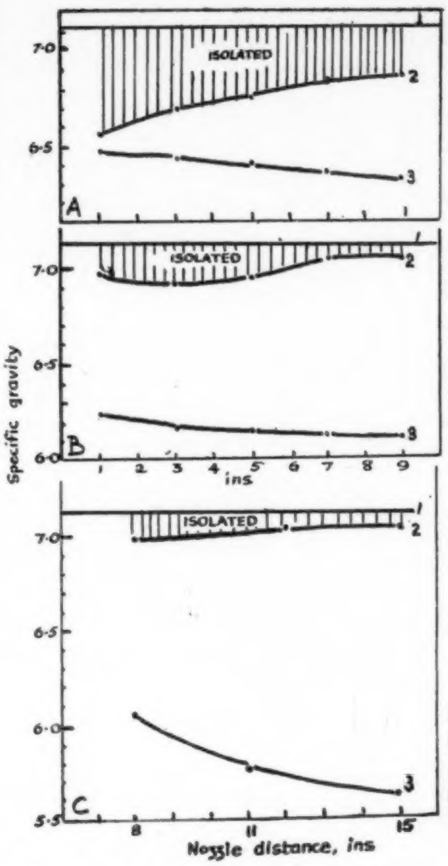
The various experimental conditions investigated for a wire pistol included : (1) time of spraying, (2) the distance of the nozzle from the surface, (3) the hydrogen and oxygen pressures, (4) pressure of compressed air, (5) rate of feeding of metal wire. The metals which were investigated included zinc, aluminium, lead, monel metal, iron and V2A steel. The results are shown in Fig. 8, and the right-hand scale is × 100 or × 50 that of the left-hand scale.

Thickness of Coating.—The results given in Fig. 8a show that the thickness of coating has little effect in the case of aluminium, but greatly improves the impermeability of V2A steel and lead to gases.

Spraying Distance (Fig. 8b).—The porosity of lead and aluminium coatings increases rapidly with increasing distance of the nozzle from the surface (10 to 30 cms.), but in the case of monel and iron deposits, little effect was noticed, and with a neutral flame the compactness of V2A steel improved.

Hydrogen Pressure (Fig. 8c).—Increasing hydrogen pressure (1 to 2 atm.) decreased the porosity of all coatings,

* *Z. Metallk.* 28, 1936, 143.



A.—*Wire pistol.*

B.—*Molten metal.*

C.—*Powder.*

Curve 1, specific gravity for sound zinc.
Curve 2, specific gravity in toluene.
Curve 3, specific gravity in water.

Fig. 7.—The specific gravities of zinc sprayed by three processes.

but the greatest effect was produced in the aluminium and lead coats.

Excess Oxygen in the Flame (Fig. 8d).—Excess oxygen increases the porosity in lead and zinc, decreases it in iron and copper, and has little effect on aluminium coats.

Air Pressure (Fig. 8e).—An increase in the air pressure had practically no effect on the porosity of aluminium, zinc and copper, but had a pronounced effect on lead and V2A coatings: the former becoming very porous (2·0 to 2·6 atm.), and the latter more compact (1·8 to 2·6 atm.)

Wire Feed (Fig. 8f).—In all cases, an increase in the rate of feeding the wire tended to increase the porosity owing to the failure to liquify the wire.

The optimum conditions for the production of sprayed coatings according to German practice using hydrogen are given in Table I, but these possibly vary when coal gas is used.

TABLE I.
Conditions for Producing Sound Castings (Everts).

Metal.	Spraying Distance, In.	Hydrogen Pressure, Atm.	Oxygen Pressure, Atm.	Air Pressure, Atm.	Wire Feed, Ft./Min.	Improvement.
Copper	4	2·4	2·4	2·7	12·2	13
Aluminium	2	2·4	2·3	2·7	18·3	6,600
Zinc	2	1·8	1·65	2·4	15·2	430
Lead	2	1·6	1·5	2·0	13·4	330
V2A	8	1·8	1·7	2·7	4·9	4
Steel	8	1·8	1·9	2·2	3·7	8

The last column in Table I gives the improvement in soundness of the coatings, as compared with that produced under ordinary conditions.

The effects of various after-treatment of the coatings are given in Table II as average values.

TABLE II.
Effect of Treatments on Soundness of Coating (Fold Increase). Everts.

Metal.	Heating.	Grinding.	Polishing.
Copper	11	19	137
Aluminium	11	235	320
Zinc	11	100	40
Lead	—	610	270
V2A	5	4·9	11
Steel	3	5·4	800

TABLE III.
Type of Porosity.

Metal.		No. Pores per $Mm.^2$	Size of Pores, Mm.
Copper	Porous	22	0·002 –0·007
Copper	Dense	5	0·0025
Aluminium	Porous	22	0·002 –0·02
Aluminium	Dense	45	0·0003–0·0007
Zinc	—	1,000	0·0001–0·001
Lead	Dense	5,000	0·0001–0·00001
V2A	—	20	0·0005–0·001

Everts also attempted to estimate the number of pores in the coatings by direct counting under the microscope. The results are given in Table III, which shows that copper and aluminium had comparatively few pores of large diameter, while zinc and lead had a much larger number of pores, but their diameter was much smaller.

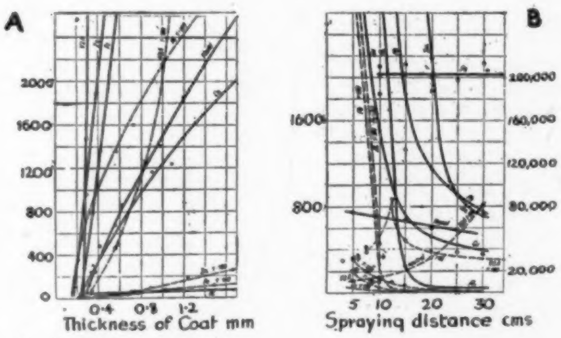


Fig. 8.—Effect of sprayed conditions on porosity (wire pistol) by Everts.

In measuring the permeability of the coating to water, it was found that the coating became impermeable after reaching a certain critical compactness, 160,000, 90,000, sec./litre/cm.[2] for aluminium and zinc, respectively. Permeability to water also depends on the size of pores and thickness of over 0/2 mm. was required (1 atm. pressure).

Chemical Tests

Several tests have been suggested and used for indicating the porosity of metallic coatings on steel depending on the formation of coloured areas by the reaction of the reagent with the exposed iron. One of the earliest of these was the ferricyanide test in which

Potassium ferricyanide	1 part.
Sulphuric acid	1 part.
Water	4.50 parts.
Gelatin	50 parts.
Potassium ferrocyanide	20 grms.
Magnesium sulphate	1 grm.
Water	500 cc.

the water reagent was applied to the coating. Pores in the coating produce blue spots. This test is suitable for coatings which are electro-positive to iron (i.e., tin, copper). Bare spots in zinc coatings are protected by the sacrificial action of the zinc and the test has to be modified. Garre† claims that this can be done by the addition of oxalic acid and hydrogen peroxide ; iron inclusions and bare areas give rise to blue coloration, but differentiation between them is possible. Alternatively, the whole sample can be made anodic the application of an external E.M.F. under which condition blue spots are produced at the pores. Using a 4-volt. accumulator and a platinum cathode, the following solution has been suggested :

Vacuum Method

Another possible method which might be used to estimate porosity is a vacuum method; the principle of which is illustrated in Fig. 9. A standardised specimen is placed in a closely-fitting chamber S, and sealed up tightly. The chamber A is empty, but of known volume, and preferably equal to the free space in S. Chamber S is connected to a vacuum pump P, and is evacuated to a low and known pressure. The connection to the pump is closed, the two chambers connected together, and the change in reading of the manometer is noted. The porosity can be calculated from the following formula :

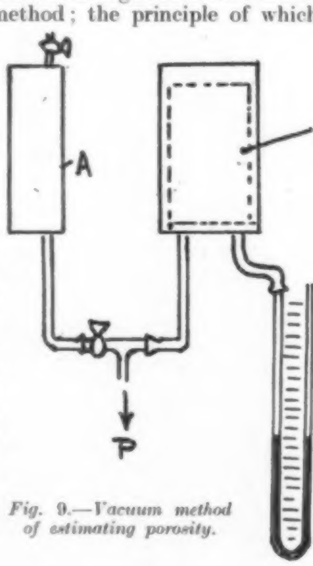


Fig. 9.—Vacuum method of estimating porosity.

$$S = Va\frac{P_2}{P_1 - P_2}(Vs - V)$$

where S = pore vol. ; V = vol. of specimen ; Vs = vol. of chamber S ; Va = vol. chamber A ; P_2 = equilibrium manometer reading ; P_1 = evacuated manometer reading.

The accuracy can be checked by measuring the porosity of a solid piece of metal. Unfortunately, the volume of the sprayed specimen has to be found by density measurements, or by computation.

Reduction of Porosity

In order to increase the solidity of sprayed coatings mechanical treatment, such as scratch brushing, rolling, hammering, may be used in limited applications. The pores are compressed as shown in Fig. 3. The rumbling in barrels of small sprayed articles is a good example of the treatment, and has the advantage of producing an improved appearance.

Another method consists in filling the pores with a second constituent such as a low-melting-point metal which runs into the pores when the article is heated ; or doping with a paint or varnish. The latter has been recommended by Reininger‡ and the principle is illustrated in Fig. 3. Suitable copal or bakelite varnishes penetrate into the pores of the sprayed metal, and after drying form intermediary layers which cement the metal grains together and to the base-plate, and thus produce stronger coatings. Metal pieces having varnished coatings can be deformed plastically to a greater degree than those with ordinary coating without stripping and grinding of the coats is facilitated. Electro-chemical corrosion due to the formation of galvanic couples at the boundary between the base metal and the coating is greatly reduced when specimens are exposed to water, salt or acid solutions. On the other hand, certain workers have shown that stove enamelling of sprayed coatings did not improve their resistance to atmospheric and marine corrosion. Organic solvents such as alcohol, acetone, turpentine, destroy the varnish layers.

On account of the porosity in sprayed coatings an excellent bond is provided for paints which are subsequently applied, although it will be noted that a greater quantity of paint is required to cover a given area. This extra weight of paint may be disadvantageous in the case of aircraft where weight is of vital importance. One interesting method of reducing porosity is by spraying a powder consisting of zinc and glass with the result that an enamel-like finish is produced.

Zinc is sprayed more frequently than other metals, and in coatings produced under the best commercial practice, the slight porosity does not deter greatly from the usefulness of this mode of fighting corrosion.

New Atom Disintegrating Equipment

The study of the transmutation of elements is now to be undertaken by an industrial concern with ample facilities for financing and engineering such work, instead of confining this investigation to small institutions and academic laboratories. The possibility of disintegrating the atom and of producing new products, with resultant development of new processes, appears to be within sight, now that the Westinghouse Research Laboratories are constructing the largest unit in the world for conducting experiments in the field of nuclear research.

It is recognised that the basis of transmutation of elements is a matter of nuclear reaction, but scientists are still learning about processes, energies and sequences of operations. This new atom disintegrating equipment consists of a large pear-shaped tank, 47 feet high and with a maximum diameter of 30 feet, mounted above a two-story building.

The tank will contain a powerful electrostatic direct current generator and a 40 foot vacuum tube. Voltages in excess of 5,000,000 will be used, to accelerate sub-microscopic particles of matter up to speeds varying between 30,000,000 and 100,000,000 miles per hour. These sub-microscopic particles will be directed to bombard targets of various material at the end of the 40 foot vacuum tube ; the particles will be counted, measured and identified by special instruments during their passage through the tube and they will then leap from the end of the tube through thin metal windows, striking the targets with a velocity great enough, it is believed, to penetrate the hard centres or nuclei of the atoms and produce new combinations or substances.

It is hoped that the work of the Westinghouse atom disintegrating equipment will prove of inestimable value in the study of the structure of matter.

† Garre Arch. Eisenhuttenwesen, 1930, 9-17.

‡ Trans. Faraday Soc. 1935, 31, 1,268.

American Society for Testing Materials

At the recent annual meeting of the above Society, the tenth technical session was devoted to steel, cast iron and metallography, while at the last session a number of papers and reports on non-ferrous metals were presented. In this article brief reference is made to some of the papers.

A NEW technique for identifying steel structures and locating flaws by means of balancing wave tests was discussed by Mr. C. Kinsley; the idea is based on the assumption—verified by the author in every case examined—that hysteresis loops uniquely characterise any ferro-magnetic material with respect to its structure and physical condition. The magnetic "finger-print" is standardised and recorded by using a simple sine wave of magnetising force which produces a cyclical magnetic flux in a secondary testing circuit. This quantitatively analysed by the test apparatus into its equivalent Fourier's series of harmonic terms, these then being recorded as the complete characterisation of the material.

No change could be made in the material without a corresponding change in one or more of the constituents of its characteristic series of terms and no different combination of analysis, metallurgical structure or physical condition have yet been found that would produce a duplicate of the characteristic equation of the specimen.

Weld Metal

Weld metal was discussed as an engineering material and from the point of view of testing, and the determination of the properties of weld metal has necessitated supplementing of routine testing methods with special physical tests, chemical analyses and metallurgical examinations. These have established that the qualities of weld metal are dependent upon welding technique and controllable procedures.

Cast Iron Tests

A very interesting paper on the effect of span on the transverse test results for cast iron was included, the authors of which concluded that the modulus of rupture increases with decreasing span and the modulus of elasticity decreases with decreasing span; but whilst deflection decreases with decrease of the span the decrease is considerably less than the conventional beam formula would indicate, the amount of the effect of changing span depending largely upon the qualities of the iron.

Another paper dealt with tests which showed that the tensile strength and compressive strength of grey cast iron vary with the size of the castings from which the test specimens were prepared. It was suggested that, in giving the tensile strength of cast iron, the size of the casting from which the specimens was taken should be quoted.

Other papers reported the results of tests made to study the influence of surface defects on specimens held in flat and V-notch grips; on threaded end specimens, both solid and hollow, to determine the effect of the interior portion on the distribution of stress over the cross section; and on specimens with ends threaded on both the outside and inside, to study the effects of the location of the threads on the strength of the specimen. It was found that different castings made from the same pouring varied in strength from 10 to 11 per cent., that the hollow and solid specimens had nearly the same strength, with an advantage of 2 to 5 per cent. in favour of the solid, and that in each of these types there was little difference in strength between inside and outside threaded specimens. Surface finish is not particularly important in tension and small superficial defects did not produce stress concentrations which appreciably affected strength, the greatest source of stress concentrations being caused apparently by an abrupt change of cross section near the ends of a specimen, but a slight increase in cross section over a short length does not cause a detectable cross concentration.

Creep Tests

A progress report on long time creep tests of 15% chromium, 8% nickel steel and 0·35% carbon steel was presented, aiming to produce data from which comparisons of creep rates over long and short periods could be made. Increasing rates of creep were shown on the 18% chromium, 8% nickel steel at 8,345 lb. per sq. in. at 1,200° F., thus increasing the differences between the actual deformations measured and the values obtained from the 2,000 hour test, by extrapolation. The 0.35% carbon steel also showed that, for dependable extrapolation, it is essential to have knowledge of the strain-hardening characteristics of the steel.

The Graphitic Phase in Grey Cast Iron

The need for a metallographic system of classification of the graphite phase in gray cast iron inspired Messrs. W. E. Mahin and J. W. Hamilton to present a paper proposing standard charts for this purpose. The authors included a chart made up of eight photomicrographs at a magnification of 100 diameters, showing graphite flake sizes from less than $\frac{1}{16}$ in. to over 4 in. length, and a chart showing graphite flake types. They stated it was their experience that mixed flake sizes usually exist as groups composed largely of one size with the balance largely of another size, these areas falling into two general classes; dentrites of widely varying size and rosettes $\frac{1}{64}$ in. or larger in actual diameter.

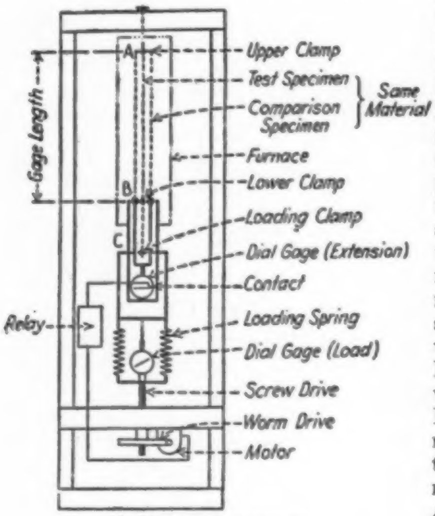
The desirable procedure for comparison appeared to be to use as low a magnification as possible over the widest possible field without sacrificing the accuracy of the measurement. A method has been developed involving the use of a wide-field binocular microscope at comparatively low magnifications. With a magnification of 10 to 25, all or most of the surface of an average micro-section may be seen at one time. Flake size readings are then obtained by comparison with a standard piece mounted beside the specimen on the stage of the microscope; this standard may consist of a small polished block of stainless steel with eight small marks inscribed at one edge and with diameter or length corresponding to the mean actual length of the eight flake sizes referred to in the authors' chart. The flake size chart and the type chart and a magnification of 100 diameters may be used for checking the accuracy of measurements made at the lower magnification and for use in connection with extremely small sizes of graphite flakes.

Fatigue Properties of Non-Ferrous Sheet

In the session devoted to non-ferrous metals, a paper was presented by Messrs. Greenhall and Gohn on the fatigue properties of non-ferrous sheet metals in which it was shown that nickel silver sheet of 0·015 to 0·017 mm. average grain size has a higher endurance limit than similar material of larger grain size. This paper also confirmed the previous conclusion that dispersion hardening of alpha brass by the addition of nickel silicide increases the endurance limit and that cold work raises the endurance but this is not in proportion to the increase in tensile strength. A marked increase in the endurance limit of type K monel metal, aluminium alloy 17S and beryllium-copper alloys was shown by age-hardening.

A very informative paper was presented by Mr. John Boyd, under the heading of "The Relaxation of Copper at Normal and at Elevated Temperatures," furnishing experimental information upon the interdependence of stress, temperature, time and amount of cold work.

In many applications the conditions are different from those obtaining during the usual creep tests, as for example two bolts tightened on rigid flanges and held at a given temperature will have their length kept practically constant but their stress will be found to decrease, raising some doubt as to whether decrease in stress can be predicted from creep tests. The phenomenon of the decrease of stress at constant length is known as relaxation, and a special apparatus was used. This is illustrated in Fig. 1. The gauge length (A to B) is 20 in. and specimens of $\frac{3}{16}$ in. diameter and of pure copper were used. Comparison specimens were of the same material, and diameter as the test specimens and were 20 in. long. Extending downward from point B are four steel rods which carry the relative motions of points A and B out of the furnace to the dial gauge and this gauge has a contact which engages the pointer at a predetermined value of the extension. When contact is made it cuts out a 4–5 volt grid bias on a grid glow relay which is connected to start the motor. Load is applied to the specimen at point C through the small frame and springs and varied by the motor driving the screw up and down, extending or releasing the springs. The dial gauge will respond and cause the motor to operate on a change of length of approx. $\frac{1}{15000}$ of an inch over the gauge length of 20 in., corresponding to a change in stress of about 10 lb. per sq. in.



Relaxation Apparatus

The 40 in. furnace provides 10 in. of heated length beyond each end of the gauge length of the specimen. In all tests the specimen, with extensometer in place, was put in the heated furnace and allowed to remain without load for one hour before applying load. Temperature was controlled by a device employing the relative differences in expansion between a quartz rod and a nickel tube, operating a vacuum switch connected so as to interrupt the entire 4–8 amp. furnace current.

Copper was chosen for the test specimens for its relative simplicity and for its importance in electrical engineering. It was taken from hard-drawn 0·204 in. diameter copper wire, cut to length, straightened (after heating by resistance) and annealed at 570° C. for two hours in an electric furnace with hydrogen atmosphere.

Results of the tests showed that the relaxation of copper at room temperature and probably up to 200° C. may, for practical purposes, be represented by an expression of the form :—

$$\sigma = \sigma^* \left[1 - A \cdot \log\left(1 + Bt\right)\right]$$

where σ = the stress at any time t, σ^* = the initial stress, and A and B are constants.

Further, it was shown that a marked increase in relaxation takes place when the temperature is raised above about 80° C. At 200° C. the stress is estimated to fall to about 20–25% of its initial value in a service time of 20 years ; the recovery effects tend to decrease the creep rate found in the early part of a relaxation test, and the dissimilarity between the speed laws for decreasing and for increasing stress gives rise to rather large amounts of relaxation.

Corrosion Testing Methods for Copper Alloys

Corrosion testing methods for copper alloys were discussed by Messrs. D. K. Crampton and N. W. Mitchell who have classified corrosion phenomena according to cause and result, the tests incorporating as many as possible of both the causes and the resultant forms of corrosion. It was shown that alternate-immersion and water-line tests do incorporate many of the causes. and all of the forms of corrosion with their variations.

The causes and forms of corrosion were classified as follows :—

Causes of Corrosion.

(a) *Primary Causes :*
- *Electrochemical Corrosion—*
  - Evolution of hydrogen or replacement of metal.
  - Local cell action.
    - Difference in metal composition (galvanic action).
    - Differential aeration.
      - Water line.
        - (Attack at water line also due to causes other than differential aeration).
      - Deposit attack.
    - Differential movement.
    - Differential concentration.
    - Difference in temper.
    - Differential illumination.
- *Chemical Corrosion—*
  - Direct chemical reaction.
    - Sulphur.
    - Halogens.
    - Oxygen.
    - Organic chemicals.

(b) *Acceleration Factors :*
- *Stress Corrosion—*
  - Combined stress plus corrosion.
- *Corrosion Fatigue :*
  - Combined fatigue plus corrosion.
- *Special Destructive Cavitation or Impingement—*
  - Physical destruction of surface film followed by electro-chemical corrosion.

Forms of Resultant Corrosion.

Uniform or General Thinning.

Pitting—
- Shallow.
- Deep.
- Elongated.

Selective Solution—
- Removal of one constituent of an alloy.
  - Dezincification :
    - Local.
    - Uniform.

Intercrystalline Corrosion :
- Penetration along the grain boundaries.

Very interesting data was obtained from water-line tests in a solution of 0·5% malic acid plus 0·5% sodium chloride, at a temperature of 60°C. (within 1° C.), for 30 days, the evaporation loss being just overcome by adding distilled water continuously. The six specimens were suspended from a fibre disc with the centre of the strip specimens at solution level and no possibility of electrical contact between specimens.

Alloy Composition, %.	Percentage Loss of Tensile Strength (Avg. of 5 Specimens)	Standard Deviation, Root Mean Square.	Form of Corrosion.
Cu 99·96, P 0·035	92	7	Pitting at water line
Cu 55·43, Zn 44·57	29	16	Local dezincification
Cu 69·99, Zn 30·01	45	22	Local dezincification
Cu 64·72, Zn 35·28	42	15	Uniform dezincification
Cu 59·37, Pb 0·16, Zn 40·47	58	18	Uniform dezincification
Cu 70·97, Sn 1·14, Zn 27·89	17	3	General thinning
Cu 67·66, Si 1·02, Sb 0·09, Zn 31·23	3	3	General thinning
Cu 89, Ni 5, Al 3, Sn 3 (nominal) .	1	1	General thinning

Manufacture and Characteristics of Hiduminium RR. Alloys

By J. TOWNS ROBINSON *

Invented by Messrs. Rolls-Royce, Ltd., and developed and introduced by Messrs. High Duty Alloys, Ltd., The Hiduminium RR. series of alloys have successfully filled a pressing demand. In this and succeeding articles the characteristics and manufacture of these alloys, and also some general aluminium alloys, will be discussed, in order to familiarise those in industry with the vital and important part played by aluminium alloys.

IN recent years the ever-increasing demand for lightness, stability, strength, and highest possible efficiency in engine performance and design has made it imperative that the production of aluminium alloys should be developed upon entirely different lines to those employed in the past, and this was visualised some years ago by those responsible for the formation of Messrs. High Duty Alloys, Ltd. As a result of this, a new technique was developed which I would venture to say has been responsible for the present high quality and efficiency of aluminium alloys, and definitely marked a new era in the application of scientific principles to industry.

It must be remembered at this stage that its progress was rapid as compared with that in other industries, and the advantages gained were immediately incorporated into design and their applications utilised. The immense strides made in recent times by the aero engine industry can be instanced apart from others, such as transport and constructional work. It is no exaggeration to say that this epoch in the history of aluminium alloys is responsible to a very great extent for the present-day progress in general mechanical and engineering practice.

Aero engine piston in Hiduminium "Y" alloy.

It is well to consider the characteristics of aluminium alloys before this development in their manufacture took place. Take the casting alloys for instance; they were subjected to a multitude of complaints or diseases, which was looked upon as something inherent to their nature, and hence borne with an inevitable tolerance, believing them to be incurable. In the first place, the quality of the original metal and alloys used was not recognised in its true perspective, the melting conditions were definitely bad, the effects of pouring temperatures and the absorption of furnace gases little understood, the methods of casting were more or less of a " hit-and-miss " nature, due to the lack of fundamental knowledge of their properties. This environment, therefore, naturally resulted in porous castings, pinholing, speckiness, low and irregular physical properties, which meant low strength and subsequent failures in service, and generally a lack of faith in the serviceability of aluminium alloys.

The forgeable alloys were probably a little more fortunate in their environment, but here again no definite technique was available, and recourse was naturally made to steel practice, which was totally unsuited to aluminium alloys, the result being weakness due to overheating, variable physical properties, lack of defined and controlled grain flow, incipient cracking, and again service breakages attributable to the inevitable properties of the alloys.

This must not be interpreted in the light of any lack of knowledge on the part of our various scientific institutions, but rather in the lack of the application of that knowledge by those in the aluminium industry. In recent times, however, there has been also a definite stimulus in scientific research and development on aluminium alloys both by the well-known institutions and also individual investigators, and a very wide field has been covered.

This work has included the quality and the effect of impurities on the virgin metals, the study of the various alloying systems, melting conditions and furnace design' the effect of absorbed gases, the use of flux for cleansing' degasing reagents, etc., all of which have been essential for the production of sound castings and ingots for wrought purposes. Further research has been done on the working conditions of wrought material, thermal treatments, the effect of crystal grain size and growth, X-ray crystallographic investigation of the lattice structure and systems, corrosion resistance and protective coatings.

Not only has the company which I represent maintained the keenest interest in these researches and helped to stimulate them, but has also instituted systematic collaboration with the various scientific authorities, both in this country and abroad, and, what is still more important, has

Aero engine cylinder head. Sand cast Hiduminium RR. 53

* Chief Metallurgist, Messrs. High Duty Alloys, Ltd.

Chemical Composition—Hiduminium Alloys.

Constituent.	RR. 50.	RR.53.	RR. 53C.	RR. 56.	RR. 59.	RR. 60.	RR. 66.	HD. 72.	RR. 82.	DU.	HDY.
Cu	1·5	2·2	1·3	2·1	2·2	2·5	0·4	4·2	—	4·3	4·0
Ni	0·9	1·3	0·9	1·3	1·3	—	1·5	—	0·6	—	2·0
Ti	0·18	0·07	—	0·07	0·1	—	—	—	0·2	0·2	—
Fe	1·15	1·0	1·15	1·2	1·2	1·5	0·7	—	—	—	—
Si	2·4	1·27	2·8	0·6	0·85	1·0	—	—	—	—	—
Mg	0·1	1·55	0·5	0·8	1·55	1·0	4·95	1·5	1·0	0·65	1·5
Mn	—	—	—	—	—	0·5	0·25	0·6	0·6	0·5	—
Zn	—	—	—	—	—	—	—	—	—	—	—

Heat Treatments for Hiduminium.

Type of Alloy.	Annealing.	Solution Treatment.	Quench.	Ageing Treatment.	Quench.
Hiduminium RR. 56 and RR. 59	½ to 4 hours. 360° C.	2 hours. 530° C.	Water, 70° C.	15–20 hours. 170° C.	Water or air
Hiduminium Du Brand and 72	½ to 4 hours. 360° C.	1–3 hours. 490°–500° C.	Water	5 days natural ageing.	—
Hiduminium "Y" alloy	½ to 4 hours. 360° C.	2 hours. 520° C.	Boiling water	5 days natural ageing.	—
Hiduminium RR. 66	½ to 4 hours. 360° C.		No hardening	treatment.	
Hiduminium RR. 53 and 53C	—	2–4 hours. 510°–525° C.	Boiling water	15–20 hours. 170° C.	Water or air
Hiduminium RR. 50	—	—	—	10–20 hours. 170° C.	Water or air
Hiduminium S.R. alloy	—	2–4 hours. 510°–535° C.	Water	10–20 hours. 155–175° C.	Water

persevered with the policy of applying the knowledge gained from these researches in co-operation with both designers and manufacturers to present problems and a practical solution of them.

Apart from this, however, an intensive investigation and research programme has been constantly in progress, through suggestions formulated mainly by technical meetings of the staff, and controlled by a selected research committee. It is only by this form of contact, both scientific and practical, that the production of high quality alloys can be maintained and future progress ensured.

Problems and unforeseen difficulties are constantly arising both in the manufacture and in the practical use or serviceability of aluminium alloys, chiefly owing to yet unknown and uncontrolled factors which can only be speedily solved by scientific methods. Apart from this, present conditions render it imperative that constant research work should be taking place to both improve and discover new alloys to maintain the ever-increasing demands made upon aluminium alloys and to use their advantage to the full.

Most of the older casting alloys have completely faded into oblivion, but of the wrought alloys, both "Y" alloy and Duralumin still hold and maintain definite spheres. Duralumin has been improved upon in light of recent knowledge by certain modifications, but the old standard composition is still maintained for the majority of purposes.

The advent of the Hiduminium RR. alloys, both casting and wrought, came at a period when they were greatly needed, and marked a decided advance in high strength alloys. Their commercialisation under scientifically controlled conditions of production opened up new fields in the use of light alloys which were readily explored and utilised.

By the addition of magnesium up to, say, 10%, combined with small percentages of other elements to aluminium, a series of alloys have been produced both for casting and wrought purposes which have exhibited striking corrosion-resistant properties combined with fairly good physical properties. These alloys have proved rather more difficult to work and control than the other forgeable alloys, but their particular characteristics have been readily applied to practical uses.

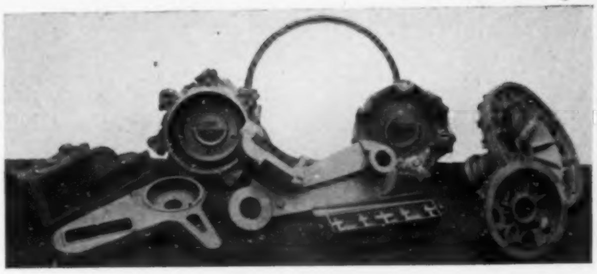
In the first place, it will be well to enumerate the various alloys produced by Messrs. High Duty Alloys, Ltd., and their uses, most of which are naturally well known, and have been described and commented upon from time to time. Nevertheless, it will complete a sequence to tabulate them herewith.

All these alloys have been specially developed and their composition so constructed and adjusted to give distinctive characteristics for their particular purposes, and this has been accomplished by close practical and scientific co-operation.

Physical Properties—Hiduminium Alloys.

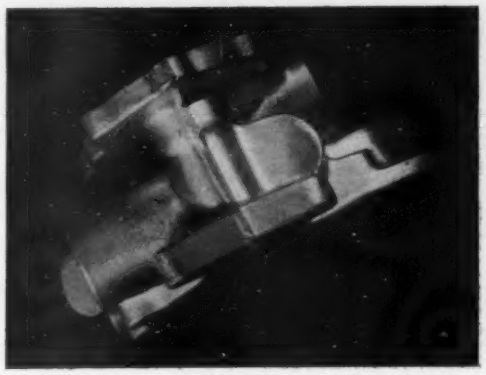
Alloy.	Condition.	0·1% Proof Stress, Tons per Sq. In.	Maximum Stress, Tons per Sq. In.	Elongation, % on 2 in.	Brinell Hardness.
RR. 50	Sand cast, H.T.	9·0	11·0	2·5	65
	Chill cast, H.T.	11·0	13·0	4·0	70
RR. 53	Sand cast, H.T.	15·5	16·0	0·5	129
	Chill cast, H.T.	19·0	20·0	0·5	129
RR. 53c	Sand cast, H.T.	18·0	19·0	2·0	129
	Chill cast, H.T.	19·0	22·0	2·0	129
RR. 66	Sand cast	6·0	10·0	4·0	72
	Chill cast	6·0	14·5	12·0	70
	Forged soft	9·0	20·0	15·0	95
	Forged hard	15·0	24·0	15·0	107
RR. 56	Forgings, extrusions and sheet, H.T.	21·0	27·0	10·0	129
RR. 59	Pistons, H.T.	20·0	25·0	6·0	129
	Forgings, H.T.	21·0	27·0	10·0	129
RR. 60	Forged, H.T.	22·0	28·0	8·0	129
	Extrusions, H.T.	24·0	30·0	8·0	129
RR. 72	Sheet, H.T.	17·5	28·0	15·0	129
	Extrusions, H.T.	18·0	28·0	10·0	129
Hiduminium Du.	Forgings, H.T.	15·0	25·0	15·0	110
Hiduminium "Y"	Forgings, H.T.	14·5	25·0	15·0	110
	Pistons, H.T.	14·5	22·0	8·0	110

The above are minimum figures for specification purposes. H.T.—Heat-treated.



Miscellaneous sand castings in Hiduminium RR. 50.

In the manufacture of high-grade alloys, the first basic essential or foundation is the use of high-quality virgin aluminium, and the other metals used in the hardener alloys, such as copper, nickel, manganese, and titanium alloys. Each of these metals must be of a recognsed purity with the minimum of impurities present, because segregation of such impurities or an aggregate of impurities can have very far-reaching effects and detrimental circumstances in the finished material. The use of secondary



A Stamping in Hiduminium RR. 56

exist, or considerable quantities of non-metallic inclusions or other defects be present, then the ultimate result is that a very large quantity of metal is effected and finally a high scrap percentage.

Inferior quality hardener alloy can therefore cause endless

AIR MINISTRY SPECIFICATION.

CASTING ALLOYS—		
*Hiduminium RR. 50	Sand and die castings for general purposes	D.T.D. 133B.
* ,, RR. 53	Sand die castings, for use on elevated temperatures, air cooled cylinder heads, pistons, etc.	D.T.D. 131A, D.T.D. 238
* ,, RR. 53C	High-strength alloy for general purposes, not quite so good as RR. 53 at temperature, but slightly more ductility. For lever, reciprocating parts, etc.	D.T.D. 309, D.T.D. 313.
* ,, RR. 66	Sand and die castings requiring high resistance to corrosion	In preparation.
WROUGHT ALLOYS—		
*Hiduminium RR. 56	High strength alloy for general purposes. Crankcases, reduction gearcases, con. rods, extruded sections, etc.	B.S.S. L 40, D.T.D. 179, D.T.D. 184, D.T.D. 206, D.T.D. 22A, D.T.D. 246.
* ,, RR. 59	High strength alloy for use at elevated temperatures. Pistons, cylinder heads, etc.	B.S.S. L 42.
* ,, RR. 60	High strength alloy for general purposes. Extruded sections, tubes, sheet, strip stampings and forgings.	In preparation.
,, RR. 72	Single treatment alloy. Extruded sections, tubes, sheet and strip.	D.T.D. 270, D.T.D. 280, D.T.D. 290.
,, RR. 82	Soft solid drawn tubes for fuel pipes, etc.	D.T.D. 310.
,, Du Brand	General purpose wrought alloy. Bars, extruded sections, tubes, sheet and strip, forgings and stampings, airscrew blades, etc.	B.S.S. 5L1, B.S.S. 4L3, B.S.S. 3T4, B.S.S. L39, D.T.D. 147, D.T.D. 150.
,, "Y" alloy ...	Wrought alloy for use at elevated temperatures. Pistons, cylinder heads, etc.	B.S.S. 2L25, B.S.S. L43.
* ,, S.R. alloy	Soft alloy for sealing rings for cylinders	D.T.D. 128.
ALUMINIUM COATED ALLOYS—		
*Hiduminium RR. 56	Corrosion-resisting sheet and strip	In preparation.
,, 72	Corrosion-resisting sheet and strip	D.T.D. 275.
,, Du Brand	Corrosion-resisting sheet and strip	B.S.S. L38.

*Covered by British Letters Patent and patent in all principal countries.

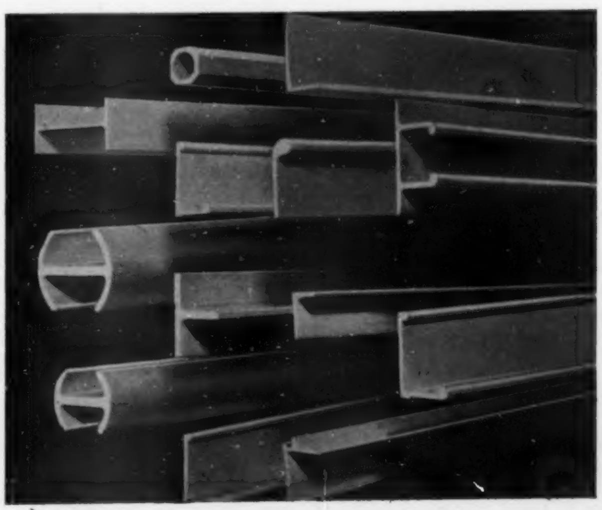
or reclaimed metals have a definitely limited sphere, and their use will lead only to a multiplicity of troubles in manufacture, even when purification by fluxing and degasing has been carried out to a high degree. The quality and preparation of all the alloys used in the make-up of the final alloy is of paramount necessity, and scientific control at this early state or first stage in the manufacture cannot be too highly stressed.

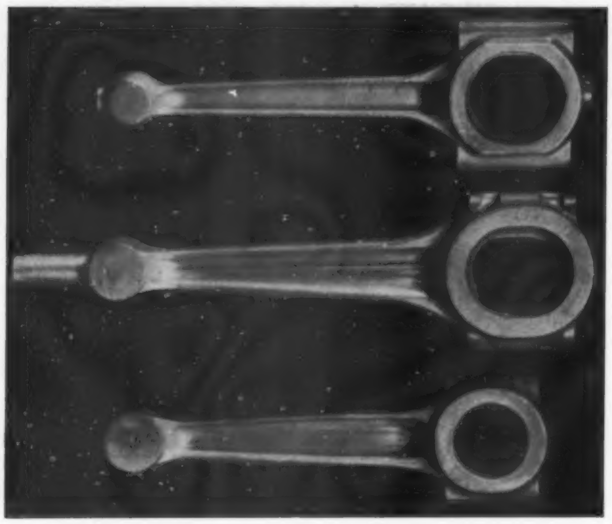
The knowledge and record of the chemical composition of all materials used should be instituted, and the requisite elements graduated between well-defined limits of tolerance, based again upon a complete knowledge of their factors and specific purposes. No chance or "trust-to-luck" methods can be taken, otherwise variations in composition, and, what is more important still, undesirable impurities will naturally creep in from most unexpected sources. Prevention is better than any applied "cure," as the application of the "cure" in the form of various adjustments results in both loss of time, loss in production, and valuable remelting losses.

In the preparation of the hardener alloys, such as the copper-aluminium, nickel-aluminium, manganese-aluminium, titanium-aluminium, etc., their treatment in melting must be carefully studied and controlled. It must be remembered that a melt of one of these alloys is incorporated in the make-up of a considerable quantity of melts of the final alloy, and that, for instance, should segregation

trouble and prove a very expensive item. Melting conditions embody a wide range of pitfalls which can exert detrimental influences and prove very troublesome in their

Extruded Sections in Hiduminium RR. 56





Connecting rod stampings in Hiduminium RR. 65.

isolation and detection. For instance, the absorption of furnace gases, bad and defective furnace lining, which results in the presence of minute particles of foreign matter, prolonged heating giving rise to high gas and oxide contents, excessive temperature during the process again effecting the gas and oxide, etc. If the correct conditions are abused, then the fundamental duties or effective action of the flux in cleansing is very considerably impaired. An important axiom in foundry technique is cleanliness, and this must be rigidly enforced to ensure results. It is surprising how a small amount of oxide or dross entrapped in a pot of metal will lead to such large quantities of minute non-metallic inclusions in finished parts.

The cleansing and degasing by the use of a suitable flux is a process which needs a reasonable amount of care and attention in its application. Ineffective fluxing can have more detrimental effects than not fluxing at all. The constitution of the flux with its respective fusion point should be known, because if films of semi-liquid flux become entrapped in the molten metal, an intermixture of flux will therefore be retained upon solidification, and this will cause outbursts or eruptions on the skin of the finished parts, particularly if the said parts are subjected to high-temperature heat-treatment.

During pouring of the molten metal, whether it be for castings or ingots for wrought purposes, turbulence or agitation of the metal must be strictly avoided owing to the affinity of aluminium alloys in the molten state for oxygen with the formation of oxides and scum which become entrapped in the solidified metal, causing porosity and weakness, or deposited on the outside skin, again resulting in defective areas.

It is obvious, therefore, even to the laymen, that scientific control must be instigated from the commencement in the manufacture of aluminium alloys, and must start with the raw materials used. It is imperative that a complete knowledge of the quality and characteristics of the original materials be known and duly recorded.

This article has been more in the nature of a general review, and has only very briefly touched upon the wide range of scientific principles to be applied, but in the series to follow, the characteristics and methods employed in the control of the Hiduminium alloys will be dealt with in detail.

A scheme for the formation of a new company, with a capital of £1,000,000, to erect and operate a plant at Jarrow, for the manufacture and rolling of steel has been made possible by the participation of the Consett Iron Co., Ltd., the Nuffield Trustees and the Bankers' Industrial Development Co., and by the agreement of the Government to provide loan money.

Reorganisation of Research in Soviet Ferrous Metallurgy

A conference recently held in the Soviet Union adopted a number of resolutions of far-reaching importance. Part of the discussion concerned the question of research, and it was decided that all works with an annual output of 300,000 tons and more of rolled metal, in addition to their existing shop laboratories, should institute central works laboratories, whose functions would include not only research in problems of immediate interest to the plant in question, but also in prospective problems. The object of this decision is to relieve the scientific research institutes of the need to concentrate on narrow specific subjects of interest to a particular plant, thus enabling them to concentrate on more general subjects.

At the same time, it was decided that the Central Administration of the Metallurgical Industry of the U.S.S.R. should give a definite lead to the research institutes under its control on the nature of the subjects on which it is desired they should concentrate. For a more authoritative solution of various urgent problems in theory and design, the conference agreed to appeal to the Academy of Sciences of the U.S.S.R. to take a more active part in working out scientific problems relating to ferrous metallurgy.

As a result of the conference decisions, a radical reconstruction will be carried out in the work of designing. The three existing designing bodies—Gipromez, Stalproekt, Giprostal—will be merged into a single institute under the control of the Central Administration of the Metallurgical Industry, with specialised local departments. The Leningrad department of the Institute, for instance, will be responsible for the general planning and designing of entire works. The Moscow department will concentrate on the designing of open-hearth and other industrial furnaces, and on the solution of thermo-technical problems. The Kharkov department will concentrate on the design of agglomerating works, pipe foundries and their plant, as well as on the reconstruction of works and shops in operation. In addition to directing its network of designing organisations, the new Institute will control the work of the factory technical bureaux, will keep account of the designing staff, and supply them with information and material.

A function of the Institute will be to co-ordinate designing work with the plan of capital construction and of output. In order to improve the technical level of designing work, designers are to be kept in close touch with the scientific research bodies.

The reorganisation of the work of designing is to be started immediately, with a view to its completion before the end of the year.

American Exchange Paper

The American Foundrymen's Association has selected Dr. James T. MacKenzie, chief metallurgist, the American Cast Iron Pipe Co., Birmingham, Ala., to present the Association's official exchange paper before the 1938 meeting of the Institute of British Foundrymen. Dr. MacKenzie's paper will review research work on chemical changes of cast iron in cupola melting. He is one of the foremost world authorities on this subject, and has been a very prominent leader in the activities of the A.F.A. and other technical associations. At the 1937 convention of the A.F.A., Dr. MacKenzie was awarded the Association's J. H. Whiting gold medal for important and practical work in the advancement of grey iron foundry practice.

This paper is one in a series instituted in 1920 to promote the exchange of foundry knowledge between members of the various national associations of America and Europe. Some 300 papers have so far resulted from this arrangement. Further, a series of international foundry congresses has been instituted, being controlled by a committee of representatives of the various national associations, including the A.F.A., the Institute of British Foundrymen, and the foundry associations of France, Belgium, Italy, Poland, Czechoslovakia, Germany and Holland.

Cavitation Erosion of Metals

Experimental investigation of the cavitation phenomenon is still in its early stages, but some recent work on the subject, which is discussed in this article, provides some interesting data.

THE erosion of ship propeller blades, of pump impellers, and of hydraulic turbines, is a type of failure of metallurgical materials which has not been exhaustively studied. This form of attack is ascribable to cavitation in the liquid medium, and is particularly likely to occur in modern high-speed hydraulic machinery of the rotary type, and results in a roughening of the metal surface, which has somewhat the appearance of a pitting type of corrosion, but corrosion products may be substantially absent. Cavitation itself produces a direct loss of energy, and its erosive effect, which roughens the metal surfaces involved, increases the friction, thus producing a further energy loss as well as eventual failure. The most disturbing fact is the extended and rapid erosion and corrosion of parts where cavitation occurs. In some installations of high-speed turbines and pumps, replacements of casings and blades have been necessary after only a short time, due to excessive cavitation damage, and parts of injector pumps on steam locomotives require replacement after only 4,000 to 15,000 running miles, depending on the design and the material used. Experimental investigations of the cavitation phenomenon is still in its early stages Interesting data has, however, been published in a recent issue of *Metals and Alloys*, by W. C. Schumb, H. Peters, and L. H. Milligan[1] of work carried out at Massachusetts Institute of Technology.

In the equipment used intense vibrations of frequency approximately 9,000 cycles per second are generated by longitudinal vibration of a hard-drawn nickel tube, the lower end of which is closed by a cap which is immersed in the liquid, so that cavitation occurs directly beneath the cap. The tube is driven at its natural vibration frequency by an oscillating electric current tuned to the proper frequency, and vibrates because of the magnetostrictive properties of nickel. The lower end of the nickel tube has a nickel or brass plug silver-soldered into it, and the projection portion is threaded so that removable caps of various metals can be screwed into it. In some work, with solutions corrosive to metals, a cap of inert erosion-resistant material was made of moulded boron carbide. As considerable heat is generated in the vibrating tube, it has to be dissipated, otherwise vibration ceases, consequently the nickel tube has to be water-cooled uniformly. The electrical coils which are made of asbestos-covered wire, are cooled by blowing air on them with a fan during operation of the apparatus.

From direct microscopic observations of the ends of the nickel tube, the maximum limits of movement were found to be about 0·1 mm. apart. The frequency, determined stroboscopically, was found to be about 8,700 cycles per second, so that the maximum acceleration was approximately 15,000 times that of gravity. During operation of the vibration unit, a stream of fine bubbles extends downwards in the liquid below the flat end of the metal cap, and the liquid is in rather violent agitation, circulating downward below the cap and upwards adjacent to the walls of the containing vessel. The erosion pattern produced on the cap has a diameter of about 1 cm., and the degree of erosion increases towards the centre of the cap. The chips produced by the cavitation erosion are like shreds of metal of very irregular shapes. They settle to the bottom of the vessel and are usually not fine enough in size to become colloidally dispersed. Under the microscopic, chips of aluminium, copper, brass, etc., are bright and shiny, indicating little if any oxidation, and cold-rolled steel is slightly yellowish over the erosion area.

In the first series of experiments, five different metals were tested by vibrating in distilled water at room temperature for several consecutive periods of exactly 5 mins. each. The temperature rise in the water was 11° to 12° C. above room temperature in each vibration period. The metal caps were of different lengths, depending on the specific gravity of the metal used and ranged from 7 to 14 grms. each. The average results obtained from several tests are given in Table I.

TABLE I.
AVERAGE RESULTS OF TESTS OF METAL CAPS.

Metal.	Cavitation Erosion (Mm. Loss in Weight per 5-min. Period).
Ordinary brass	10
Aluminium (commercially pure)	30
Copper (commercially pure)	27
Tobin bronze	7
Cold rolled steel	0·5

The value for the steel is the average for the first two tests on two different specimens, and is low relative to the other values, because a fresh, smooth surface tends to erode less rapidly at first. The total erosion for cold-rolled steel, however, was very slight, so that the surface did not depart much from its original smooth condition.

In the next series of experiments, the metals tested were brass, cast iron, cold-rolled steel, and 18/8 stainless steel. Two samples of each alloy were tested in tap water at 20° C., the testing time consisting of four 30-min. intervals. The weight losses of the different materials were compared with the weight loss of cast iron for equal intervals of testing time, and a relative scale of resistance determined. In accordance with this scale, the 18/8 steel was about 5·5 times more resistant than cast iron, cold-rolled steel 1·5 times more resistant, and brass 0·8 times as resistant This order of resistance is in general agreement with observations of cavitation damage in practice.

For the investigation of the effect of the fluid properties on cavitation corrosion, samples of an aluminium alloy were vibrated for 40 mins. at 10-min. intervals. Tests were carried out in (1) tap water, (2) 20% sodium chloride solution, (3) methyl alcohol, and (4) carbon tetrachloride, and in each case the effect of temperature was determined, the different temperatures being attained by passing steam or cooling water into the bath or by adding ice to it. The properties of the liquids tested varied in wide range as regards vapour pressure, density, viscosity, etc. The results obtained indicated that under the prevailing cavitation conditions a temperature of maximum weight loss exists in the vicinity of 40° to 50° C. in water and in 20% sodium chloride solution. No maximum was found in methyl alcohol over the range studied, but in carbon tetrachloride a maximum was found around 20° to 35° C. Relative rates of cavitation at room temperature were 1·0 for water, 1·15 for 20% sodium chloride, 0·10 for methyl alcohol, and 0·10 for carbon tetrachloride. The severity of cavitation damage appears to depend on more than one property of the liquid, and properties that possibly have an effect are density, vapour pressure, solubility of gases, surface tension, viscosity, thermal properties, compressibility, etc. The influence of these various properties are discussed, but the few data available do not permit the drawing of definite conclusions as to their relative importance.

[1] *Metal and Alloys*, 1937, vol. 8, No. 5 pp. 126-132.

TABLE II.

Sand-blast Tests on Different Metals.

Metal.	Depth of Sand-blast Penetration after 30 Blasts at 25 lb. Air Pressure. Mm.	Relative Cavitation Erosion.
Cold-rolled steel	0·36	4
Copper, commercially pure	0·37	27
18-8 stainless steel	0·41	1
Aluminium, commercially pure	0·52	30
Tobin bronze	0·60	7
Cast iron	0·79	8
Brass	1·05	10

Experiments were also made on resistance to sand-blast impact abrasion and its relation to cavitation erosion considered. The sand-blast tests were made, using No. 30 grain size of "E-1 Alundum" abrasive grain. Results of these tests and the average relative cavitation erosion tests are given in Table II.

There appears to be little direct relationship between the sand-blast values for the different alloys and their relative cavitation erosion. The results for cold-rolled steel, Tobin bronze, cast iron, and brass agree fairly well with each other, but there are discrepancies with the aluminium and copper possibly due to the fact that these are soft metals and are influenced by plastic deformation. There is nothing in the available data, however, to indicate why 18/8 stainless steel is so relatively resistant to cavitation erosion compared even to cold-rolled steel.

The Fatigue Resistance of Lead and Lead Alloys

FAILURE by intercrystalline cracking of lead cable sheathing led to the initiation in 1924 of a comprehensive investigation by the British Non-ferrous Metals Research Association on the properties of lead and lead alloys. During the years that the Association has been conducting this research extensive information has been collated on the fatigue resistance of lead and lead alloys. These results have now been collated and tabulated in Research Report No. 440.*

The materials covered in the report include lead and lead with small additions of tin, antimony, cadmium, calcium, barium, copper, nickel, and bismuth respectively; and tin plus cadmium, antimony plus cadmium, tin plus antimony, tin plus cadmium plus copper, antimony plus cadmium plus copper, and bismuth plus magnesium. In addition, a few results of tests conducted at 100° C. in air are given, as well as some selected results showing the effects of surrounding media and protective coatings.

During the early stages of the work it was concluded that this intercrystalline cracking of cable sheathing was a fatigue failure due to vibration of the cable, either in transport or in service, and the successful remedy was to use alloys having a higher resistance to fatigue than that of pure lead.

Whilst the remedy was ascertained, it was, however, revealed that there was a scarcity of available knowledge on the properties of lead and its alloys, and the work of the Association was directed towards a general investigation of the mechanical properties of these metals in relation to their use for cable sheathing, water piping and rolled sheet. All the alloying additions can be introduced without difficulty by well-known methods, except in the preparation of lead-calcium and lead-barium alloys, where the rapid oxidation of the additions during melting may necessitate the adoption of special precautions to ensure uniformity of composition.

Each of three brands of lead used in the tests was of 99·99% purity; material described as "cold-rolled" was reduced about 75% in thickness from the ingot form, the percentage reduction of the ingot in commercial extrusion is assumed to be at least 90%; material referred to in the results simply as extruded was reduced from 1½ in. diameter ingots to 1 in. diameter rod at 250° C., and certain of the lead-calcium alloys were pre-heated and extruded at 275° C. The test-pieces were 0·564 in. diameter at the mid part, except certain of the pure lead pieces, which were 0·75 in. diameter.

Of the tests in air at room temperature, the endurance limit (tons per sq. in., semi-range of stress in 10 million cycles) for three brands of pure lead was shown to vary from 0·17 to 0·21. In the lead-tin group the highest value was given by an alloy of lead plus 3·0% tin, cold rolled, the value being 0·54. A cold-rolled specimen of the same alloy, but heated 250° C. for 1 hour, and an extruded test-piece gave equal values of 0·48.

With the exception of three specimens, which were heated at 250° C. for 1 hour, the tests with lead-antimony showed that the increasing addition of antimony resulted in higher fatigue resistance properties, these ranging from 0·16 for lead plus 0·01% Sb to 0·65 for lead plus 1·00% Sb.

Lead-cadmium alloys gave values from 0·42 for a 0·3% Cd addition (cold-rolled and heated 250° C. for 1 hour), 0·475 for the same alloy cold-rolled only, 0·65 for a 0·5% Cd addition (cold-rolled), and 9·59 for the 0·5% Cd alloy specimen cold-rolled and heated for 1 hour at 250° C.

Lead-tin-cadmium showed values of from 0·31 to 0·57, the lower being for 0·4% Sn, plus 0·15% Cd additions, and the higher for a 1·5% Sn and 0·25% Cd addition. The only combination of lead-antimony-cadmium tested was of lead plus 0·5% Sb, plus 0·25% Cd. Two test-pieces were used, both extruded commercially. The value for one specimen was 0·74 and for the other, which was heated 250° C. for 1 hour, 0·72.

Lead-calcium, too, showed steadily increasing values as the percentage of calcium was raised, ranging from 0·37 for a 0·013% Ca addition to 0·83 for a 0·041% addition; all tests being of specimens extruded at 250° C.

Lead plus 0·02% barium had an endurance limit of 0·49, and with 0·04% Ba, 0·70. A commercially extruded test-piece of lead-tellurium (0·057% Te) gave a reading of 0·50, but a slight increase in the tellurium content to 0·067% produced a lower figure, 0·34.

The maximum figure with a 0·06% addition of copper to lead was 0·28; lead plus 0·1% nickel had a limit of 0·24; and lead plus 0·09% magnesium, 0·48. Lead-bismuth and lead-oxygen (saturated) both gave rather low figures, with a maximum of 0·22 for the 0·15% bismuth addition, and 0·245 for an addition of 0·005% O_2.

Fairly comparable results were obtained from lead-tin-cadmium-copper, and lead-antimony-cadmium-copper; these being 0·55 for lead with 1·5% Sn, 0·25 Cd, and 0·11% Cu contents, and 0·58 max. for 0·5% Sb, 0·25% Cd, and 0·08% Cu additions. A high value was shown by lead-bismuth-magnesium (0·15% Bi plus 0·05% Mg), this being 0·80 for an extruded specimen.

Tests in air at 100° C., of commercially extruded specimens, gave the following results: Pure lead, 0·08; lead plus 1·5% tin and 0·25% cadmium, 0·28; lead plus 0·5% antimony and 0·25% cadmium, 0·40; and lead plus 0·06% tellurium, 0·33.

Results of tests to show the effects of surrounding media and protective coatings on the fatigue resistance of the metals, gave the following maxima:—

Material.	Medium or Coating.	Semi-range of Stress. Tons per Sq. In.	Endurance, Millions of Cycles.
Pure lead, extruded	Rape oil	0·30	12·9 (U)
	Vaseline	0·40	9·8 (U)
Lead plus 0·4% Sn, plus 0·15% Cd, heated 250° C. for 1 hour.	Neutraline oil	0·36	11·4 (U)
Lead plus 1·5% Sn, plus 0·25% Cd, extruded	Petroleum bitumen	0·80	9·3, 10·1 (U)
	Bitumen emulsion coating	0·67	10·5
	Black enamel, L.K. 3391	0·75	9·8 (U)
Lead plus 0·5% Sb, plus 0·25% Cd, extruded	Rape oil	0·85	12·1 (U)
Lead plus 0·09% Mg	Rape oil	0·55	11·2

* Research No. 18. "The Fatigue Resistance of Lead and Lead Alloys." By H. Waterhouse, M.Met. British Non-ferrous Metals Research Association, Regnart Buildings, Euston Street, London, N.W. 1. 2s. post free.

Reviews of Current Literature

Gases and Metals

Described as an introduction to the study of gas-metal equilibria, this book deals with the adsorption, diffusion, and solution of gases in metals, and defines the fundamental principles while collating the available data relating to gas-metal equilibria.

Adsorption has been studied very largely in connection with catalytic processes, and much of the work on this subject has been done on materials specially prepared as catalysts, these often being finely divided metals prepared by saturating an inert spirit with a salt of the metal, which is subsequently reduced in hydrogen.

The early experiments and hypothesis of Faraday are mentioned. It will be remembered that Faraday described experiments on the reaction of hydrogen and oxygen at the surface of platinum plates, believing that the platinum itself did not play any chemical part in the reaction, but that the molecules of the gases, being condensed on its surface, were in far closer proximity to each other, and therefore in a more favourable condition for reaction to occur. He also investigated the "poisoning" effect of carbon monoxide on the catalytic activity of his platinum plates in promoting oxygen-hydrogen combination, and attributed the effect to the presence of an adsorptive film of carbon monoxide which hindered the adsorption of the other gases.

When a gas molecule is adsorbed on a metal surface, heat is given up. This is called the heat of adsorption, and its quantitative determination is of importance, since it throws some light on the nature of the binding forces involved.

A high heat of adsorption is naturally associated with chemical adsorption, and a lower heat with purely physical adsorption. The heat associated with the adsorption of 1 grm. molecule of gas can either be determined directly from measurement of the rise in temperature of the adsorbent or calculated from the adsorption isotherms.

The author refers to the fact that the effect of one gas on the adsorption of another is of great practical importance, but has been less thoroughly investigated than the adsorption of a single gas. He mentions that the presence of two gases in contact with a metal surface often leads to catalytic action, to promotion of chemical reaction between the two gases that would not take place in the absence of the metal surface. The action of catalysts in promoting this chemical reaction between gases is undoubtedly related to their power of adsorbing one or both of the reactants; as a rule, one gas is more strongly adsorbed than the other, and the rate of reaction is then proportional to the pressure of the weakly adsorbtive gas. Thus, with copper at 0° C. ethylene is very strongly adsorbed as a mono-molecular layer, independently of the pressure; hydrogen is only weakly adsorbed, and the hydrogenation of ethylene to form ethane is proportional to the hydrogen pressure only. It thus appears to be a uni-molecular reaction. But at 250° C. neither gas is strongly adsorbed, and the rate of reaction is proportional to the pressure of each gas, and now appears as a bimolecular reaction.

The earliest observations on the phenomenon of gas diffusion through solid metals were described in 1863, when the permeability of iron and platinum to hydrogen were revealed. During the next 40 years it was found that many other metals would allow hydrogen to diffuse through them, and it is now known that hydrogen, oxygen, nitrogen, and possibly some compound gases, such as CO, can diffuse through a small number of metals, but that the rare gases, such as helium and argon, do not diffuse through any metals. Gases can be extracted from nearly all metals by heating them *in vacuo*.

The early experiments showed that the rate of diffusion increased rapidly with the temperature of the metals, and was also dependent on the pressure of the gas. The fate that nascent hydrogen, produced by electrolysis at the surface of a metal, diffuses more readily than molecular hydrogen at the same temperature, indicates that the gas may only diffuse in the atomic state. It is believed that gas diffusion normally takes place through the lattice . . . the gas passing between the metal atoms. The most important variables are the temperature of the metal, the pressure of gas on each side, and the thickness of the metal.

The effect of gases on the mechanical properties of metals is of great importance, and is discussed fully in this book.

Absorbtion or solution is a natural corollary to the study of adsorption and diffusion, and the author considers this as the study of the equilibrium conditions between the gas and the metal, involving the existence of one or more phases, and different types of equilibrium are encountered. A gas may be absorbed by a metal with the formation of a definite compound, or it may be in true solution at one temperature, but form a compound if the temperature is changed. Also, the gas absorbed by a metal may be disassociated and distributed as atoms throughout the metal lattice.

Nitrogen is only soluble in those metals which are capable of forming nitrides, whilst molecular nitrogen is not readily absorbed by iron unless the surface has been activated; such activation may occur in service as the result of abrasion. Nitrogen is much more soluble in liquid than in solid iron, and is, at all temperatures, proportional to the square root of the nitrogen pressure. This gas may be absorbed by steel during arc welding, up to 0·15–0·20% by weight, in the welded metal, but the absorbtion is less in oxy-acetylene welding and seldom exceeds 0·02% N_2.

The nitrogen, if in excess of the soluble limit of 0·13%, separates as plate-like crystals of Fe_4N. Annealing at 800° C. results in precipitation of the nitride mainly in the grain boundaries. Oxygen is soluble to some extent in most metals, but in most cases an oxide phase appears when the limit of solid solubility is exceeded. Many molten metals are capable of dissolving large quantities of oxygen, but in freezing the excess oxygen is precipitated as an oxide. The effects of these three factors of gas-metal equilibrium on various metals are clearly described and analysed, together with many useful records of experiments, formulæ, and illustrations.

The author has confined himself to the general principles underlying the equilibria between gases and metals, and make no attempt with their practical application, but these principles, together with the collection of available data relating to gas-metal equilibria, will be found invaluable in the solution of these problems.

By Colin J. Smithells, M.C., D.Sc. Chapman and Hall, Ltd., 11, Henrietta Street, Covent Garden, London, W.C. 2. 18s. net.

Patents for Inventions

There are many legal points concerning patents that are not generally known, one of the most important being that a patent is not an absolutely guaranteed monopoly, but is of the nature of a contingent privilege, which shall be effective provided it is in accordance with law, or non-effective if found contrary to law.

For instance, a patent may be invalid and contrary to law if lacking in subject matter, novelty, utility, or inventive merit; or if the applicant is not entitled to apply for or receive the patent, or if the specification of the invention upon which the patent is founded is insufficient, inexact or misleading. These points and many others appertaining to the consideration of patents are explained clearly and fully in this book.

One extract will be of interest to the inventor who has had no previous experience of protecting or marketing his ieas and gives sound advice on the question of whether to apply for a patent before or after submission of the invention or idea to some manufacturer. The inventor

must always be the applicant, or at least one of the applicants. The inventor, or inventors, may also associate other persons (not inventors) in the application, such as capitalists, etc., but the inventor cannot wholly sell or assign his rights of application so as to permit others to make applications alone. Thus, inventions when unprotected are not saleable, for it is ueselss to buy an invention when the right of applying for patent cannot be sold with it. Inventors would not deem it wise to disclose unprotected inventions, partly from the risk of their ideas being appropriated by others and their priority lost, partly from the possibility of their patents when afterwards taken proving void from the disclosure (which fact the purchasers would also have in view), and partly from the fact that inventions, for which their authors do not deem it necessary to expend the comparatively small cost of efficient protection, will usually prove to be not worth buying.

The fifteen chapters of the book deal with the nature and validity of patents, their enforcement and value, the nature and object of provisional protection, methods of obtaining both protection and patent, the title and specifications, the nature and object of searches, amendments of specification covered by patents of addition, foreign and colonial patent factors, negotiation of patents, and a chapter on stamp duties and agency charges.

The book is concluded with a chapter on trade marks and designs, and with advice in brief.

By REGINALD HADDAN, published by Sir Isaac Pitman & Sons, Ltd., Kingsway, London, W.C.2. Price 3/6 net.

Creep of Non-ferrous Metals and Alloys

THE available information relating to the creep characteristics of non-ferrous metals and alloys has been summarised in a 20-page booklet published by the British Non-ferrous Metals Research Association.

The selected data includes information on copper and copper alloys, nickel alloys, lead, aluminium, and aluminium alloys. Numerical values are set out and tabulated in a form convenient for immediate reference, with composition of materials, and there is an index to all the metals and alloys mentioned in the report.

Although it has been known for a long time that metals undergo slow deformation or "creep" after subjection to high temperatures and stresses for prolonged periods, really systematic investigation over long periods has only been conducted in comparatively recent years. The data obtained has been used by engineers in preference to results derived from tests of short duration. This booklet provides a very useful and clearly tabulated reference work.

By W. A. BAKER, B.Sc. Research Report R.R.A. 449. Published by the Association at Regnart Buildings, Euston Street, London N.W. 1. 2s. post free.

Catalogues and Other Publications

The application of zinc spraying for the protection of steel and iron structures against corrosion is explained and illustrated in a 32-page booklet issued by the Imperial Smelting Corporation, Ltd., of 95, Gresham Street, London, E.C. 2. As the particles of metal are practically cold when they impinge upon the article, and the rise in temperature is negligible, widely different materials can be treated, including fabrics, cast iron, paper, steel and gun cotton.

Of the many applications of zinc spraying, the illustrations show the treatment of wheels, steel pressings, the *Normandie* (in which the ventilating system, refrigeration plant, fire-proof bulkheads, many interior fittings, and the three huge funnels were zinc sprayed), bridge structures, cooling coils, steel windows and frames, ornamental gates, rivetted steel tanks, yacht hulls, electrical screening and radio valves. The three methods of spraying zinc—by molten metal pistol, powder pistol, and by the Schoop system, in which the zinc enters the pistol in the form of wire and is then melted and sprayed, are described briefly.

Edgar Allen and Co., Ltd., Imperial Steel Works, Sheffield 9,, have sent us a copy of their K 9 Tool Steel booklet. It is a new edition, and contains new illustrations, showing tools and other parts made from this steel. The booklet contains much useful information. A copy will be sent on request to Edgar Allen and Co., Ltd.

A TWO-COLOUR folder has been issued by Hadfields Ltd., Sheffield, giving stability figures, mechanical properties and tensile test results of Hecla 153 chromium-molybdenum creep-resisting steel for steam-pipe flange bolts. This steel is stated to be free from embrittlement under working conditions at temperatures in the region of 450° C., and fulfils the mechanical test requirements of B.S.I. specification No. 10, pt. 5, 1932.

THE application of aluminium in the textile industries is dealt with in a well-illustrated 36-page book, published by the British Aluminium Co. Ltd. The company logically points out that light alloys of aluminium are specially applicable in all machinery demanding members which are strong, stiff and light, which are free from rust and deterioration, and which are easily worked, machined, welded or surface treated.

The book describes the application of such aluminium alloys for carding, spinning and doubling, winding, weaving, slashing and sizing, and for various functions in the rayon industry. In regard to rayon production (the term being used to refer to all forms of the bicose product) the use of aluminium for the high-speed spinning pots is advocated and for other details of the spinning plant where acid spray is present. Aluminium poles for suspension of the hanks during drying, bobbins, storage and transport tanks, and oil tubing are all shown as possessing other desirable features in addition to lightness.

Mention is also made of aluminium for knitting, hosiery, bleaching and dyeing. Miscellaneous applications are given, briefly, there is a page devoted to aluminium paint and another on the subject of anodising. The book is complete with three pages of recommendations, including sheets, tubes, sections and castings. Copies may be obtained from the British Aluminium Co., Ltd., Adelaide House, King William Street, London, E.C. 4.

A BOOK that is of interest to electrical engineers and contractors, and to those interested in the application of aluminium generally, is that published by the British Aluminium Co. Ltd., under the title of "Overhead Transmission Lines." It describes very clearly the advantages of steel-cored aluminium conductors, both from the aspect of economy and of service, showing that this type of conductor is normally cheaper than copper conductors of equal resistance, the lower sag of steel-cored aluminium conductors allowing a saving of several feet in the height of the supports, and a further saving of some 27% in the number of supports by virtue of the longer permissible span the reduction in the number of supports involves, and a proportionate reduction in total cost of insulators, foundations, erection and way-leaves, also reduction in the cost of maintenance, etc.

Reliability and economy are in part allied. By reducing the number of supports the risk of stoppages from faults at supports—these being the most common location of faults—is reduced correspondingly.

Steel-cored aluminium conductors have a high corona limit, the core is amply protected by the aluminium envelope, and the aluminium has a high degree of resistance to atmospheric conditions in unfavourable industrial environments. The book deals thoroughly with construction of conductors, physical properties (with special reference to weights and stresses), and many recommendations as to types of joints, insulator connections and conductor erection.

Conversion tables and equivalents, and general data are included, together with a very useful section for calculating the sag of a conductor of 900-ft. span length.

Personal

Edgar Allen and Co., Ltd., announce that Mr. H. Woodhead has joined their Machinery Department for the purpose of assisting in the development of that section of this department which deals with coal-washing and allied machinery.

Mr. P. Fawcett has retired from the position of managing director of the Park Gate Iron and Steel Co., Ltd., owing to ill-health, and Mr. F. Clements has been appointed managing director in his place.

Preventing Failure of High-speed Steel

By L. SANDERSON

Much may happen to high-speed steel after it leaves the manufacturer, which may result in its subsequent failure, and in this article some practical hints are given which will assist in obtaining satisfactory results.

THE failure of a high-speed steel tool is, no doubt, one of the most irritating experiences in the modern machine shop. When the user purchases a supposedly trustworthy make of high-speed steel, sold as capable of taking heavy cuts at high speeds, it is not unreasonable of him to expect satisfactory results. When the blacksmith who forged the tool, and the operator of the machine in which it was employed, both declare their complete innocence, and blame the steel, it is not surprising if he passes on the statement to the maker. But, as a rule, tool breakdowns are attributed to the blacksmith, to whom the defective tool is sent back with instructions that he is to exercise more care. Now the smith may or may not be skilled at his job. In the first instance, he probably knows that all his craft cannot produce better results. In the second, he is probably to blame, and the steel-maker should be invited to send a demonstrator to show him how to handle the steel.

But when the smith cannot honestly be blamed, it is astonishing that the only scapegoat then chosen seems to be the steel-maker. That the actual operator may have some responsibility is not assumed nearly so often as it ought to be. It ought to be borne in mind that whereas tools and their making are the smith's craft, the machinist regards tools merely as incidentals to output, and is not likely to have the same regard for them, considered as objects.

The user often makes the mistake of trying out various kinds of high-speed steel on the same machine. A powerful section is generally employed, and heavy cuts are taken at high speeds on the most difficult material available in the shop. The very characteristics that enable a steel to function efficiently in these circumstances may be the cause of failure when the tool is set to work on normal material with a tool of delicate shape or type. No test can be regarded as entirely trustworthy if it has not been carried out under normal conditions, and that this is so is demonstrated by the admitted fact that the same steel is not invariably the best in different shops.

Examining tool failures in detail, it may be said that as a rule the chief errors by the blacksmith who makes the tool from the bar are heating too rapidly during forging, overheating, or forging at too low a temperature. In heat-treating, his principal mistakes lie in the direction of overheating, failing to get the tool hot enough to bring out the greatest high-speed characteristics, and maintaining the tool for too long a period at a high temperature.

The mistakes of the tool-grinder consist of grinding too fast, giving too great a clearance, rake, or shear, which leads to fracture, and giving inadequate shear, which causes rough cutting and blunting. And the errors of the operator consist of having too much overhang, too high a speed, too large or too small chips, and working in gritty material.

Where the steel's failure cannot be attributed to any of these mistakes, it will probably be found that the steel is primarily designed for tools of intricate form or delicate shape, where it is essential that the steel should be tough ; or it may have been forged in a coal fire, and have absorbed a percentage of sulphur and phosphorus, impurities leading to deterioration of the steel. Furthermore, if the air blast is defective, it will set up flaking of the tool on the top. It will thus be seen that tool failures should be thoroughly investigated before the steel is returned as faulty.

In this connection, it should be stressed that to test tools to destruction at excessively high speeds is a bad method. The life and advantageous cutting speed of high-speed steel tools depends on their ability to withstand wear at normal cutting speeds, without excessive heating or softening of the tool, the wear being principally caused by abrasion. This is a far more normal set of circumstances than when the tool life hinges upon the steel's ability to resist burning when extreme heat is generated at the cutting edge.

Tests that cause the tool to soften or break down far more rapidly than in normal shop use are no true test for normal use. The time element should be considered in all shop tests, and it has been said that no test is really scientific and valid unless the tool has been running for at least 20 mins. Short-time tests may be quite unreliable because of the difference between resistance to wear and resistance to heat.

A typical example of insufficient examination of tool steel failure is the following : Some high-speed steel pieces, measuring $2\frac{1}{4}$ in. × $1\frac{1}{2}$ in., for roll-turners' tools, were returned to a maker with the complaint that the steel would not work into the tools required because it was " seamy " and kept breaking short. On examination, it was found by the maker that the manner in which the forged pieces had split showed that the steel had not been properly soaked, with the result that the outer layer, where forged, had broken away from the inside. The defects were not due to seamy steel, because the pieces did not show any signs of seams, but, on the contrary, appeared to have badly broken in forging, due to not having been carefully handled in this respect. The large section made thorough soaking essential, to allow the heat to penetrate evenly through the mass before forging was begun.

Some precautions of simple type in heat-treating high-speed steel tools will prevent many failures. It is of supreme importance to heat the cutting edges, so as to obtain complete uniformity. All tools should be moved so that both sides achieve identical temperature. For milling cutters, it will be found a good plan to secure a block of pure nickel, on which they may be placed, so that the cutting edges extend over the block edges. It will be found that this helps to bring them to a uniform heat. Tools possessing a large and small cross section may be raised evenly to heat by protecting the thinner sections with asbestos for part of the time, and then removing this so that all parts obtain the requisite temperature at the same moment. Angular cutters can be set with the thin section next to the hearth floor, so that they are thereby protected by their own bulk, and the thin sections will be the last to achieve the essential temperature.

" Flaky " steel may be produced as a result of the hardening of long lengths of lathe, planer, and shaper tools, succeeded by dressing operations in which only part of the previously hardened steel is heated to annealing temperatures that would normally prevent its occurrence. Prevention of " flaky " fractures may be achieved, therefore, by annealing between successive hardening treatments.

Incidentally, it is worthy of note that high-speed steel can be annealed at a relatively low temperature. Instead of heating it to 925–980° C., it is necessary only to heat it to 700–720° C. and allow it to cool till black. It should

then be put back into the furnace, reheated to the temperature given, and maintained at that heat for half an hour.

Some users have been known to quench high-speed steel in water to anneal it. This is not advisable, and this treatment should only be employed, if at all, on steel that has not previously been hardened.

In hardening high-speed steel, the importance of not quenching the tools stone cold is to be stressed. Nothing is more liable to cause cracking than the practice of quenching cold in oil, then allowing the tools to lie on the floor for a period before tempering them. But it is certainly true that high-speed steel should be quenched down to a certain temperature before tempering, or otherwise the tool will be brittle and untrustworthy, and liable to split or snip in use. Many breakdowns of high-speed steels difficult to account for have been found due to their having been taken out of the quenching bath at too high a temperature, and then tempered before the full hardening of the steel had had time to take place.

Another point. Quenching and tempering of high-speed steel should not be carried out in one operation, because a high-speed steel tool ought to be hardened all over. For example, high-speed shanks, as on reamers and end mills which receive a good deal of stress, must not be left soft, for the reason that the hardened structure is the strongest. To harden properly, it is desirable to cool the whole tool down to 80° C. and then reheat to temper. It is feasible to employ the hardened tool without reheating to temper by permitting the frictional heat developed by use to draw the temper, but the existing quenching stresses are likely to cause the tool to crack or break before they are removed.

Ageing and Properties of Aluminium-Magnesium Alloys

RECENT experiments have been carried out by Petrov,* with the object of studying the effect of small additions of beryllium, chromium, copper and lithium on the hardness and ageing properties of aluminium-magnesium alloys. The base alloys used in these experiments contained 4 to 12 per cent. magnesium, and additions of 0·6 and 1 per cent. beryllium, 2 per cent. copper, 0·4 and 0·8 per cent. chromium, and 1 per cent. lithium were made. The alloys were cast into a chill mould of cylindrical shape, 30 mm. in diameter and 100 mm. high. The upper ends of the ingots obtained were cut away, and after annealing at 410° for 48 hours the 60 mm. high ingots were compressed at 400° to 410° C. to a height of 15 mm. and a corresponding diameter of 60 mm. The specimens were then used to determine the optimum heat-treatment temperature, the results of the heat-treatment being determined by hardness measurements. The optimum temperatures for solution heat-treatments were found to be—for the 12 per cent. magnesium alloy and the 9 per cent. magnesium alloy containing 2 per cent. copper—470° C.; for alloys with 9 per cent. magnesium, 480° C., and for all other alloys, 510° C.

After quenching, one-half of the specimens were stored at room temperature, while the remainder were artificially age-hardened at 150° for three days. Ageing at room temperature was found to have practically no effect on aluminium-magnesium alloys. Ageing at 150° C. also had only a slight effect on alloys with 4–7 per cent. magnesium. An exception to this was the alloy with 4 per cent. magnesium and 2 per cent. copper. Alloys with 9 per cent. magnesium showed a somewhat larger ageing effect. Particularly interesting results in this group with 9 per cent. magnesium were obtained with an alloy containing an addition of 0·6 per cent. beryllium. The hardness of this alloy on ageing at 150° C. increases from 81·8 immediately after quenching to 111·7 after three days' ageing. The hardening of the 9 per cent. magnesium–0·4 per cent. chromium alloy is somewhat less than that of the beryllium-containing alloy. The hardening of the alloy with 2 per cent. copper is still less, while that of the 9 per cent. magnesium binary alloy is least. Age-hardening at 150° was particularly marked in the 12 per cent. magnesium alloy, additions of beryllium and chromium again increasing the effect as compared with the binary alloy.

It is interesting to note that some experiments showed that the hardness of aluminium-magnesium alloys, after slow cooling from the solution heat-treatment temperature, was greater than that of the quenched alloys. This is probably due to the slow cooling not being slow enough to allow the aluminium-magnesium solid solution to reach an equilibrium concentration.

* D. A. Petrov. *Metallurg.* 1937. 3, p. 95.

Explosion of Aluminium Powder Dust Clouds

AN investigation has been carried out on the above subject, and the results are described by Mason and Taylor.* Experiments were made on aluminium dust suspensions in air. A vertical glass tube was used, which was closed with an aluminium head and base plates held in place and made gas tight. A weighed quantity of aluminium dust was blown into the explosion chamber by a puff of dry air of known volume and pressure. The latter was so adjusted that the aluminium powder was dispersed throughout the length of the glass explosion tube, and a trace of it appeared at the outer end of an open, large bore stopcock on the head of the apparatus. This stopcock was then closed, and the dust cloud ignited by the blowing of a thin aluminium fuse wire stretched between two leads half way up the explosion tube. The arc between the leads which forms after the disintegration of the aluminium is stopped by the blowing of a fuse in the external circuit. Changes in pressure are recorded on a rotating drum by a Crosby engine indicator reading at low pressures to $\pm$ 0·01 atmospheres.

Most of the experiments were made using 0·14 micron aluminium powder, which was found to be excellent from the point of view of forming a suspension in air. By using decreasing amounts of aluminium powder the lower limit of aluminium dust in air was gradually approached. The results obtained show that 40 mg. to 50 mg. of aluminium powder per litre may be regarded as the lower limit of explosibility. Increasing the powder content of the air from 50 mg. to 70 mg. per litre causes a slight increase in pressure, but the reaction zone is narrow and limited mainly to the region near the arc. Further increase in the powder concentration results in a certain amount of propagation of the reaction taking place. With a powder content above 110 mg. per litre, the reaction takes place with explosive violence throughout the vessel. The results obtained were compared with those of previous investigators.

A series of experiments were also carried out on the limiting oxygen content below which explosions would not occur. For this purpose a high concentration (210 mg. per litre) of aluminium dust was used which, when mixed with air, would produce a violent explosion. The proportion of oxygen in the air was then reduced in successive experiments by diluting the air with carbon dioxide until a composition was reached below which explosion would not occur. It was found that with less than 10% of oxygen there was no propagation, and the reaction was confined to the igniter zone. The reaction zone broadens and propagation begins as the oxygen content increased from 10 to 15% and the reaction becomes explosive with 16% oxygen present.

The above results were confirmed by using amounts of aluminium powder equivalent to 315 mg. per litre. Very similar results were obtained when using nitrogen instead of carbon dioxide to dilute the air, although nitrogen was found to be slightly less effective than carbon dioxide for this purpose.

* R. B. Mason and C. S. Taylor. *Ind. and Eng. Chem.* 1937. XXI. 6, p. 626.

Business Notes and News

Scottish Steel and Iron Production

The total of 157,300 tons of steel ingots produced in Scotland in June is a decrease of 4·15% from May production, but an increase of 12·6% over that for June last year. There are indications, however, that July figures will show a definite decrease, due to the incidence of the holidays, and to the custom of a 10-day shut-down for repairs and overhauls. The position is such, with departmental improvements nearing completion, that an expansion of output can be expected after the holiday period.

Pig-iron production is not affected in the same way by the holiday period, and it is probable that the output for July will be very similar to that of June. In June the figure was 40,200 tons, a decrease of 6·08% from May production, and of 3·37% from that of June last year.

Of the 67 blast furnaces in the Scottish industry as reported last quarter, only 47 now remain, and it is stated that 25 of these can be regarded as obsolete, and may be removed shortly. Five furnaces are being relined, and there is a scheme to construct two modern furnaces for Colvilles, Ltd., at Clyde Iron Works.

Large Iron Casting

The Egglescliffe Foundry, a section of the Head, Wrightson organisation, whose main works are established at Thornaby-on-Tees, have recently completed what is believed to be the largest iron casting ever manufactured by the company. The casting, which weighs 40 tons, is one section of a table for a planing machine, and as an indication of the intricate design of the job, there were 160 cores used in moulding operations.

Planing machine table casting.

The casting was of such abnormal dimensions, being close on 40 ft. long and over 9 ft. wide, that special traffic arrangements had to be made for its conveyance to Scotland, there being several places on the route with only inches to spare. This casting is part of an order for six cast-iron tables for planing machines, each table comprising one casting weighing 40 tons, and one weighing 18½ tons.

Orders for Locomotives and Rolling Stock

The majority of orders for locomotives received by Beyer Peacock and Co., Ltd., are from foreign countries, the orders on hand representing seven times the 1935 total, and two-and-a-half times that of 1936. A trading profit £11,000 is reported for 1936. During the year the Company has received orders for Beyer Garratt locomotives from Brazil, Colombia, Nigeria, Rhodesia, Sierra Leone, South Africa and the Sudan. This type of express passenger locomotive proved satisfactory on the Argentine railways, and the northern railways of France had made very satisfactory tests. During March the Paris-Calais express, with a Beyer-Garratt locomotive, completed the 184 miles non-stop at an average of 62.5 m.p.h. A certain number of Government orders are included, but these do not represent a major proportion of the Company's present business.

David Brown and Sons (Hudd.) Ltd., Huddersfield, inform us that they have occupied new premises in Birmingham, the address being Prudential Buildings, Colmore Row, Birmingham, 3. Telephone: Colmore 4288.

Some Recent Contracts

A new 18-in. mill, with an ultimate weekly capacity of 1,800—2,000 tons of various small sections, has been started up by the Skinningrove Iron Co., Ltd., and is designed to act as an auxiliary to the company's large mill. It has been designed and built by the Brightside Foundry and Engineering Co., Ltd., Sheffield.

Orders for rolling stock, to a total of £300,000, have been placed with British firms by the Buenos Aires Gt. Southern and B.A. Western Railways. These include 20 steam locomotives, 11 Diesel shunting locomotives of the lighter type, and 50 steel tank wagons. The locos. will be built by the Vulcan Foundry and the English Electric Co., of Preston.

An order has been placed with Vickers by the Great Western Railway Co. for a pair of 80-ft. steel gates, with hydraulic gate operating mechanism and hydraulically operated sluices; these being for Barry Docks. A second pair of steel gates for the No. 2 Dry Dock at East India Harbour, Greenock, has already been placed. The gates will be constructed at Barrow, and the machinery at Elswick.

Kendall and Gent (1920), Ltd., machine-tool manufacturers, of Gorton, Manchester, have announced an interim dividend of 5%. A number of Government orders have helped to place the company in the fortunate position of having sufficient orders in hand to keep them busy for the next two to three years, and a wide area of sales activity has also helped; the firm supplying plano-millers and vertical millers to Russia and Japan; screwing machinery, broaching machinery and vertical millers are sent to the Dominions.

An increase in Russian business was noticeable for the month of June, the Soviet Trade Delegation for London reporting purchases in this country during June to the value of £1,428,956, an increase of 59% over the same month last year. The total for the first six months of the year showed an even more satisfactory improvement, the £10,985,810 aggregate representing an increase of 63% over the first six months of 1936. Of this total, just over three and a half million pounds was for machinery and equipment.

The construction of an aircraft carrier (H.M.S. *Indomitable*), under the 1937 programme, will be entrusted to Vickers-Armstrong, Ltd., Barrow-in-Furness. Included in the same programme are three submarines, vessels of the *Triton* type, and of about 1,100 tons. H.M.S. *Thistle* will be built by Vickers-Armstrong, Ltd., at their Barrow works; H.M.S. *Tarpon* at Scotts' Shipbuilding and Engineering Co., Ltd., Greenock; and H.M.S. *Taku* by Cammell Laird and Co., Ltd., at Birkenhead.

Steel Rails

Of the total 60,000 tons of steel rails which are the subject of contracts placed by the L.N.E. Railway, 36·3%, or 38,250 tons, will be made in the North. 30,750 tons will be divided between Dorman, Long and Co., Ltd., and the Skinningrove Iron Co., Ltd., 6,500 tons by the Consett Iron Co., Ltd., 5,250 tons by the Lancashire Steel Corporation, Ltd., 5,000 tons by Colvilles, Ltd., 4,500 tons by the Steel Company of Scotland, Ltd., 4,000 tons by Samuel Fox and Co., Ltd., 2,000 tons by Shelton Iron, Steel and Coal Co., Ltd., and 1,000 tons each by Barrow Hæmatite Steel Co., Ltd., and United Steel Companies, Ltd., at Workington.

New Suspension Bridge

A new steel suspension bridge is to be erected over the Chriunda Gorge, on the Zambesi River, forming another connection between Southern and Northern Rhodesia. Dorman Long and Co., Ltd., have received the contract for the supply and erection of this bridge, which will have a span of 1,500 ft., and four approach spans of 40 ft. each. The main span will be supported by two steel wire cables of 8 in. diameter, anchored in tunnels in the rock on each river bank, and taken over 120-ft. high steel towers. The bridge deck will be 150 ft. above the river level (normal), and will have a concrete roadway of 18 ft. width, flanked by two footpaths.

MARKET PRICES

ALUMINIUM.

98/99% Purity		£100	0	0

ANTIMONY.

English		£83	10	0
Chinese		70	0	0
Crude		36	0	0

BRASS.

Solid Drawn Tubes	lb.	0	1	0½
Brazed Tubes	„	0	1	2½
Rods Drawn	„	0	0	11¼
Wire	„	0	0	9⅞
*Extruded Brass Bars	„	0	0	7⅛

COPPER.

Standard Cash		£57	10	0
Electrolytic		64	15	0
Best Selected		64	3	9
Tough		63	13	0
Sheets		92	13	0
Wire Bars		65	8	6
Ingot Bars		65	8	6
Solid Drawn Tubes	lb.	0	1	2¼
Brazed Tubes	„	0	1	2¼

FERRO ALLOYS.

‡Tungsten Metal Powder nominal	lb.	£0	5	10½
‡Ferro Tungsten .. nominal	„	0	5	9
Ferro Chrome, 60-70% Chr. Basis 60% Chr. 2-ton lots or up.				
NOMINAL 2–4% Carbon, scale 12/- per unit	ton	35	10	0
NOMINAL 4–6% Carbon, scale 8/- per unit	„	24	10	0
NOMINAL 6–8% Carbon, scale 7/6 per unit	„	24	0	0
NOMINAL 8–10% Carbon, scale 7/6 per unit	„	24	0	0
§Ferro Chrome, Specially Refined, broken in small pieces for Crucible Steelwork. Quantities of 1 ton or over. Basis 60% Ch. Guar. max. 2% Carbon, scale 12/6 per unit ..	„	37	0	0
Guar. max. 1% Carbon. scale 13/- per unit	„	39	0	0
§Guar. max. 0.5% Carbon, scale 13/- per unit ..	„	49	0	0
‡Manganese Metal 97–98% Mn	lb.	0	1	3
‡Metallic Chromium	„	0	2	5
§Ferro-Vanadium 25–50% ..	„	0	12	8
§Spiegel, 18–20%	ton	8	5	0
Ferro Silicon—				
Basis 10%, scale 3/- per unit nominal	ton	10	5	0
20/30% basis 25%, scale 3/6 per unit	„	14	0	0
45/50% basis 45%, scale 5/- per unit	„	12	0	0
70/80% basis 75%, scale 7/- per unit	„	17	0	0
90/95% basis 90%, scale 10/- per unit	„	30	0	0
§Silico Manganese 65/75% Mn., basis 65% Mn. ..	„	15	15	0
§Ferro - Carbon Titanium, 15/18% Ti	lb.	0	0	4½
Ferro Phosphorus, 20–25%	ton	22	0	0
§Ferro-Molybdenum, Molyte	lb.	0	4	9
§Calcium Molybdate	„	0	4	5

FUELS.

Foundry Coke—				
S. Wales	—	2	2	6
Scotland	—	1	17	6
Durham	—	1	17	0
Furnace Coke—				
Scotland	—	1	15	0
S. Wales	—	1	16	0
Durham	—	1	15	0

GUN METAL.

*Admiralty Gunmetal Ingots (88 : 10 : 2)		£87	0	0
*Commercial Ingots		70	0	0
*Gunmetal Bars, Tank brand, 1 in. dia. and upwards..	lb.	0	1	1
*Cored Bars	„	0	1	3

MANUFACTURED IRON.

Scotland—			
Crown Bars,	£13	10	0
N.E. Coast—			
Rivets	12	15	0
Best Bars	15	15	0
Common Bars	12	10	0
Lancashire—			
Crown Bars	13	10	0
Hoops	14	2	6
Midlands—			
Crown Bars	13	10	0
Marked Bars	15	15	0
Unmarked Bars	—		
Nut and Bolt Bars	11	15	0
Gas Strip	14	2	6
S. Yorks.—			
Best Bars	15	15	0
Hoops	14	2	6

PHOSPHOR BRONZE.

*Bars, "Tank" brand, 1 in. dia. and upwards—Solid	lb.	£0	1	1
*Cored Bars	„	0	1	3
†Strip	„	0	1	1½
†Sheet to 10 W.G.	„	0	1	2
†Wire	„	0	1	3⅜
†Rods	„	0	1	4¼
†Tubes	„	0	1	6¾
†Castings	„	0	1	3½

†10% Phos. Cop. £33 above B.S.
†15% Phos. Cop. £38 above B.S.
†Phos. Tin (5%) £30 above English Ingots.

PIG IRON.

Scotland—			
Hæmatite M/Nos.	£6	3	0
Foundry No. 1	5	15	6
„ No. 3	5	13	0
N.E. Coast—			
Hæmatite No. 1	6	3	0
Foundry No. 1	5	3	6
„ No. 3	5	1	0
„ No. 4	5	0	0
Silicon Iron	—		
Forge	5	0	0
Midlands—			
N. Staffs. Forge No. 4	5	3	0
„ Foundry No. 3 ..	5	6	0
Northants—			
Foundry No. 1	5	6	6
Forge No. 4	5	0	6
Foundry No. 3	5	3	6
Derbyshire Forge	5	3	0
„ Foundry No. 1	5	9	0
„ Foundry No. 3	5	6	0
West Coast Hæmatite	6	3	0
East „ „	6	3	0

SWEDISH CHARCOAL IRON AND STEEL.

Export pig-iron, maximum percentage of sulphur 0·015, of phosphorus 0·025.
Per English ton Kr.180
Billets, single welded, over 0·45 Carbon.
Per metric ton Kr.315-385
Per English ton .. £16 5 0/£19 17 6
Wire Rods, over 0·45 Carbon.
Per metric ton Kr.365-415
Per English ton .. £19 2 6/£21 15 0
Rolled Martin Iron, basis price.
Per metric ton Kr.315-330
Per English ton .... £16 5 0/£17 0 0
Rolled charcoal iron, finished bars, basis price.
Per metric ton Kr.360
Per English ton £18 17 6
f.o.b. Gothenburg.

SCRAP METAL.

Copper, Clean	£47	0	0
„ Braziery	41	0	0
„ Wire	—		
Brass	30	0	0
Gun Metal	45	10	0
Zinc	14	0	0
Aluminium Cuttings	74	0	0
Lead	19	10	0
Heavy Steel—			
S. Wales	3	10	0
Scotland	3	6	0
Cleveland	3	7	0
Cast Iron—			
Midlands	3	5	0
S. Wales	3	10	0
Cleveland	4	2	6
Steel Turnings—			
Cleveland	2	12	6
Midlands	2	5	0
Cast Iron Borings—			
Cleveland	—		
Scotland	2	2	6

SPELTER.

G.O.B. Official	—		
Hard	£20	0	0
English	24	7	6
India	21	0	0
Re-melted	21	0	0

STEEL.

Ship, Bridge, and Tank Plates.			
Scotland	£11	10	0
North-East Coast	11	10	0
Midlands	11	10	0
Boiler Plates (Land) Scotland..	12	0	0
„ „ (Marine) „ ..	—		
„ „ (Land), N.E.Coast	12	0	0
„ „ (Marine) „	—		
Angles, Scotland	11	0	6
„ North-East Coast ...	11	0	6
„ Midlands	11	0	6
Joists	11	6	0
Heavy Rails	10	2	6
Fishplates	14	2	6
Light Rails	10	7	6
Sheffield—			
Siemens Acid Billets	11	15	0
Hard Basic .. £6 17 6 to	10	2	6
Medium Basic, £6 12 6 and	10	0	0
Soft Basic	8	15	0
Hoops	11	15	0
Manchester Hoops	11	5	0
Scotland, Sheets 24 B.G.	15	15	0

HIGH-SPEED TOOL STEEL.

Finished Bars 14% Tungsten	lb.	£0	2	7
Finished Bars 18% Tungsten	„	0	3	6
Extras :				
Round and Squares, ½ in. to ¼ in.	„	0	0	3
Under ¼ in. to ⅛ in.	„	0	1	0
Round and Squares, 3 in..	„	0	0	4
Flats under 1 in. × ⅜ in.	„	0	0	3
„ „ ½ in. × ¼ in.	„	0	1	0

TIN.

Standard Cash	£262	15	0
English	262	15	0
Australian	—		
Eastern	261	0	0
Tin Plates I.C. 20 × 14 box ...	1	5	6

ZINC.

English Sheets	£36	0	0
Rods	31	10	0
Battery Plates	—		
Boiler Plates	—		

LEAD.

Soft Foreign	£22	10	0
English	23	15	0

* McKechnie Brothers, Ltd., Aug. 9. † C. Clifford & Son, Ltd., Aug. 9. ‡ Murex Limited, Aug. 9.
Subject to Market fluctuations. Buyers are advised to send inquiries for current prices when about to place order.
§ Prices ex warehouse, Aug. 9.

FILE THIS IN YOUR CABINET

You will then be able to refer to contents of previous issues easily.

METALLURGIA.

Contents.

For AUGUST, 1937.

ADVERTISERS' ANALYSIS

Acids
Imperial Chemical Industries, Ltd., Imperial Chemical House, London, S.W. 1.

Aluminium
Aluminium Union, Ltd., Bush House, London, W.C.2.
British Aluminium Co., Ltd., King William St., London, E.C.4.
High Duty Alloys, Ltd., Trading Estate, Slough.
Wm. Mills, Ltd., Birmingham.
Northern Aluminium Co., Ltd., Bush House, London, W.C.2
Rudge Littley Ltd., West Bromwich.

Anti-Friction Metals
McKechnie Bros., Ltd., Rotton Park St., Birmingham.

Brass and Bronze
Clifford, Chas and Son, Ltd., Birmingham
Manganese Bronze & Brass Co. Ltd., Handford works, Ipswich.
McKechnie Bros., Ltd., Rotton Park St., Birmingham.

Burners
Nu-Way Heating Plants Ltd., Macdonald Street, Birmingham.

Casehardening Compounds
Amalgams Co., Ltd., Attercliffe Rd., Sheffield.
Kasenit Ltd., Henry St., Bermondsey St., London, S.E. 1.

Castings (Iron)
Rudge Littley Ltd., West Bromwich.
Wallwork, H., and Co., Ltd., Roger St., Manchester.

Castings (Non-ferrous)
Magnesium Castings and Products, Ltd., Slough.
Manganese Bronze & Brass Co. Ltd., Handford Works, Ipswich.
William Mills, Limited, Grove Street, Birmingham.
Mond Nickel Co., Ltd., Thames House, Millbank, London, S.W. 1.
Northern Aluminium Co. Ltd., Bush House, Aldwych, London, W.C. 2.
Sterling Metals Ltd., Coventry.

Coke-Oven Plant
Gibbon Bros., Ltd., Albert Road, Middlesbrough.
Woodall Duckham, Vertical Retort & Oven Construction Co., (1920), Ltd.

Crucibles
Morgan Crucible Co. Ltd., Battersea Works, Church St., Battersea, London, S.W. 11.

Electrodes
British Acheson Electrodes, Ltd,, Sheffield.

Extruded Sections
McKechnie Bros., Ltd., Rotton Park St., Birmingham.

Extruded Rods and Sections
McKechnie Bros., Ltd., Rotton Park St., Birmingham.

Fluxes.
Foundry Services Ltd., 285, Long Acre, Nechells, Birmingham.
Imperial Chemical Industries Ltd., Dept. C.6, Imperial Chemical House, London, S.W. 1.

Foundry Preparations.
Foundry Services Ltd., 285, Long Acre, Nechells, Birmingham
Imperial Chemical Industries Ltd. Dept. C.6, Imperial Chemical House, London, S.W. 1,

Furnace Arches
Liptak Furnace Arches Ltd., 59, Palace Street, Victoria Street London, S.W. 1.

Furnaces (Electric)
Birmingham Electric Furnaces, Ltd., Erdington, Birmingham.
Demag Electrostahl, Germany.
Electric Furnace Co., Ltd., 17, Victoria St., London, S.W. 1.
General Electric Co., Ltd., Magnet House, Kingsway, W.C. 2.
G.W.R. Electric Furnaces, Ltd., Belgrave House, Belgrave St., London, W.C. 1.
Integra Co., Ltd., The, 183, Broad Street, Birmingham.
Kasenit Ltd., Henry St., Bermondsey St., London, S.E. 1.
Metalectric Furnaces Ltd., Cornwall Rd., Smethwick, Birmingham
Morgan Crucible Co. Ltd., Battersea Works, Church Street, Battersea, London, S.W. 11.
Siemens Schuckert, Ltd., New Bridge Street, London.
Wild-Barfield Electric Furnaces, Ltd., Elecfurn Works, North Road, London, N. 7.

Furnaces (Fuel)
British Furnaces Ltd., Chesterfield.
Burdon Furnace Co., 136, West Princes Street, Glasgow.
Cassel Cyanide Co. Ltd., Room 170F2, Imperial Chemical House, London S.W.1.
Dowson and Mason Gas Plant Co., Ltd., Levenshulme, Manchester.
Gibbons Brothers, Ltd., Dudley, Worcestershire.
Incandescent Heat Co., Cornwall Rd., Smethwick, Birmingham.
James Howden & Co. Ltd., 195, Scotland St., Glasgow, Scotland.
Kasenit Ltd., Henry St., Bermondsey St., London, S.E. 1.
Ofag Ofenbau, Düsseldorf, Germany.
Priest Furnaces Ltd., Albert Road, Middlesbrough.

Fused Blocks
Imperial Chemical Industries Ltd. Dept. C.6, Imperial Chemical House, London, S.W. 1.

Gas
British Commercial Gas Association, Gas Industry House, 1, Grosvenor Place, London, S.W. 1.

Gears
Wallwork, Henry, and Co., Ltd., Red Bank, Manchester
Shorter Process Co., Ltd., Savile St. East, Sheffield

Gun Metal Ingots and Rods
McKechnie Bros., Ltd., Rotton Park St., Birmingham.

Hardening Metals
Shorter Process Co. Ltd., Savile St. East, Sheffield.

Ingots (Non-Ferrous)
McKechnie Bros., Ltd., Rotton Park St., Birmingham.

Machine Tools
Sanderson Brothers and Newbould Ltd., Sheffield.

Magnetic Separators, Clutches, Chucks, and Lifting Magnets.
Electromagnets, Ltd., 48, High Street, Erdington, Birmingham.

Motors (Electric)
Metropolitan-Vickers, Ltd., Trafford Park, Manchester.

Naval Brass Ingots
McKechnie Bros. Ltd., Rotton Park St., Birmingham.

Non-Ferrous Alloys
Clifford, Chas. and Son, Ltd., Birmingham
Manganese Bronze and Brass Co. Ltd., Handford Works, Ipswich
McKechnie Bros., Ltd., Rotton Park St., Birmingham.
High Duty Alloys, Ltd., Trading Estate, Slough.
I.C.I. Metals Ltd., Kynoch Works, Witton, Birmingham, 6.

Non-Ferrous Metals
Reynolds Tube Co., Tyseley, Birmingham.
I.C.I. Metals Ltd., Kynoch Works, Witton, Birmingham, 6.
McKechnie Bros. Ltd., Rotton Park St., Birmingham.

Pig Iron
Barrow Hæmatite Steel Co., Ltd., Barrow-in-Furnace.

Presses
Eumuco Ltd., Beverley Works, Willow Ave, Barnes, London, S.W. 13.
Schloemann, A.-G., Dusseldorf, Germany.

Protection of Metal Parts for Use at High Temperatures.
Calorizing Corporation of Great Britain, Ltd., 32, Farringdon St., London, E.C. 4.

Pulverised Fuel Equipment
Alfred Herbert Ltd., Coventry.

Pyrometers
Electroflo Meters Ltd., Abbey Road, Park Royal, London, N.W. 1.
Ether, Ltd., Tyburn Road, Birmingham.
Integra Co., Ltd., 183, Broad St., Birmingham, 15.
Metalectric Furnaces Ltd., Cornwall Rd., Smethwick, Birmingham.

Recording Instruments
Dine Engineering Co. 60, Mount Street, Nechells, Birmingham.
Electroflo-Meters Co., Ltd., Abbey Road, Park Royal, London, N.W. 10.
Ether, Ltd., Tyburn Road. Birmingham.
George Kent Ltd., Luton, Beds.
Integra Co., Ltd., 183, Broad St., Birmingham, 15.
Metalectric Furnaces Ltd., Cornwall Rd., Smethwick, Birmingham

Refractories
Carborundum Co., Ltd., Trafford Park, Manchester.
J. and J. Dyson, Ltd., Stannington, Sheffield.
Kingscliffe Insulating Products, Ltd., Sheffield.
Thos. Marshall and Co., Loxley, near Sheffield
John G. Stein & Co., Bonnybridge, Scotland.

Roll Grinding Machines
Craven Bros. Ltd., Reddish. Stockport.

Roll Manufacturers
Tennent Ltd., Whifflet Foundry, Coatbridge, Scotland.

Rolling Mills
Demag, A. G., Germany.
Ehrhardt and Sehmer, Saarbrücken.
Fried. Krupp Grusonwerk A.-G. Magdeburg, Germany. Sole Agents in Great Britain : J. Rolland and Co., 2 Victoria Street, London, S.W. 1.

Continued in next column.

Lamberton and Co., Coatbridge.
Rheinische Walzmachinenfabrik, Germany.
Robertson, W. H. A., and Co., Ltd., Bedford.
August Schmitz, A.G., Germany.
Karl., Fr. Ungerer., Germany.

Silver Solder
Chas. Harrold & Co. Ltd., 283, St. Paul's Square, Birmingham.

Steels
Barrow Hæmatite, Steel Co., Ltd., Barrow-in-Furnace.
Edgar Allen & Co., Ltd., Imperial Steel Works, Sheffield.
Daniel Doncaster & Sons, Ltd., Sheffield.
Dunford & Elliott, Ltd., Sheffield.
English Steel Corporation Ltd., Sheffield.
Sanderson Bros. and Newbould, Ltd., Sheffield.
United Steel Companies, Ltd., Sheffield.

Steel Sections
Barrow Hæmatite Steel Co., Ltd., Barrow-in-Furnace.

Steel Tubes aud Sections
Reynolds Tube Co., Tyseley, Birmingham.

Steelworks Plant
Wellman Smith Owen Engineering Corporation, Ltd., Victoria Station House, London, S.W. 1.

Temperature Controllers
Electroflo-Meters Co. Ltd., Abbey Road, Park Royal, London.
Ether, Ltd., Tyburn Road, Birmingham.
Integra Co., Ltd., 183, Broad St., Birmingham, 15.

Testing Machines
Howden, T. C., and Co., 517, Fleet Street, Birmingham.

Vitreosil Combustion Tube
Thermal Syndicate, Ltd., Wallsend-on-Tyne.

Index to Advertisers.

Printed for the Proprietors, The Kennedy Press, Limited, 21, Albion Street, Gaythorn, Manchester, by Percy Brothers (1937), Limited, Hotspur Press, Manchester and London.